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# THE TAXONOMY OF THE ONYGENALES: ARTHRODERMATACEAE, GYMNOASCACEAE, MYXOTRICHACEAE AND ONYGENACEAE.

by

Randolph Sidney Currah

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Taxonomy of the Onygenales: Arthrodermataceae, Gymnoascaceae, Myxotrichaceae and Onygenaceae." submitted by Randolph Sidney Currah in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Mycology.

Dedicated to G. F. Orr,
in appreciation of his pioneering work
in isolation and classification of the
fungi reported herein.

ABSTRACT

Historically, the ascomycete families, Gymnoascaceae and Onygenaceae, have been regarded as distinct groups based on peridial morphology. Species with mesh-like peridia were placed in the Gymnoascaceae and species with more or less membranous peridia were placed in the Onygenaceae. Both families show a tendency to inhabit products of animal origin and some are agents of diseases including ringworm and deep mycoses. Both groups also contain saprophytes found on decaying or processed plant materials.

In this thesis I present a novel approach to the classification of the species formerly placed in these two families. By correlating the previously underutilized or unscrutinized characters: degradative capacity; ascospore sculpturing; and mode of conidium dehiscence; four families can be defined within the order Onygenales: Arthrodermataceae, Gymnoascaceae, Myxotrichaceae and Onygenaceae. These new family concepts disregard peridial morphology as a taxonomically valuable character above the genus level.

Most genera with the ability to degrade keratin, formerly distributed between the Gymnoascaceae and Onygenaceae, have distinct puncta on the ascospore walls, and produce rhexolytically dehiscing conidia. These taxa are placed together in a revised Onygenaceae which includes: *Ajellomyces, Amauroascus, Aphanoascus, Apinisia, Ascocalvatia, Auxarthron, Keratinophyton, Kuehniella, Nannizziopsis, Neogymnomyces, Neoxenophila, Onygena, Pectinotrichum, Renispora, Shanorella, Spiromastix, Uncinocarpus,* and *Xynophila*. Most are saprophytic on keratin in dung, soil and keratinous structures such as horn and hoof. *Ajellomyces* includes serious human pathogens. Anamorphs are either named in *Chrysosporium, Malbranchea* or *Sporendonema*, or are unnamed, and produce rhexolytically dehiscing conidia.

Keratinolytic species with smooth ascospores are placed in the Arthrodermataceae which includes *Arthroderma, Ctenomyces,* and *Nannizzia.* *Ctenomyces* is a saprophyte found on feathers and in soil enriched with keratin. The remaining two genera contain both saprophytic species found on dung and in soil enriched with keratin, and species that cause ringworm. Anamorphs frequently produce rhexolytically dehiscing phragmospores in the form-genera *Microsporum* and *Trichophyton.*

Of the remaining non-keratinolytic species, one group is markedly cellulolytic, has fusiform, hyaline ascospores, and rhexolytically dehiscing conidia either formed on apparently undifferentiated hyphae (*Malbranchea*) or on dendritic structures (*Geomyces* and *Oidiodendron*). These fungi, in the genera *Byssoascus, Myxotrichum,* and *Pseudogymnoascus*, constitute a new family, the Myxotrichaceae. They inhabit processed and unprocessed cellulosic materials.

The remaining species are placed in the Gymnoascaceae which is a heterogeneous assemblage of taxa, lacking a peridium or having in its place a mesh-like structure of more or less thick-walled cells. Ascospore walls are smooth or slightly irregular. Genera included here are: *Acitheca, Arachniotus, Gymnascella, Gymnascoideus* and *Gymnoascus*. Rhexolytically dehiscing conidia are not regularly produced in many of these taxa and none have named anamorphs. They do not form a distinct ecological group, although many appear to be largely coprophilous, being found on the dung of both herbivores and carnivores. Some are soil-borne.

Morphology and evolution of reduced or mesh-like peridia in the Onygenales may be related to a reliance on animals for dispersal and habitat formation.

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## GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**acute** -Referring to the pointed end of an appendage; or to branching which occurs at less than 90 degrees.

**aleurioconidium** -A terminal conidium released by fracture or dissolution of the supporting cell (cf. arthroconidium).

**AMD** -Herbarium, Hugo De Vries Laboratorium, Hortus Botanicus, Amsterdam, Netherlands.

**anamorph** -The morphological phase (or phases) of the life cycle of a fungus in which asexual spores are produced (cf. teleomorph, form-genus).

**anastomosis** -A fusion of one or more hyphal branches.

**annellide** -A conidiogenous cell producing conidia so that each conidium, after the first formed, is extruded through the scar left by the formation of the previous conidium. The terminus is eventually marked with a series of rings.

**apomorphic** -The presumed derived character in an evolutionary transformation series (cf. plesiomorphic).

**appendage** -Any non-sexual structure that extends beyond the perimeter of the ascoma, and that is obviously different from typical vegetative and/or peridial hyphae (see Table 3.4).

**arachnoid** -Resembling a mass of cobwebs.

**arthroconidium** -Intercalary conidium released either by rhexolytic or schizolytic disarticulation of a hypha.

**ascoma** -An individual sporocarp having asci. Used here in the sense of carpel in the angiosperms (cf. fruit body).

**asperulate** -Delicately roughened with projections or points (see Table 3.4).

**basionym** -The original name of a species, upon which a new combination is based (see Article 55.2 ICBN).

**blastoconidium** -A conidium formed from the parent cell, separated from it by a septum and released by fission through the septum.

## GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**BM** -Cryptogamic Herbarium, Dept. of Botany, British Museum of Natural History, London, England.

**BP** -Botanical Department of the Hungarian Museum of Natural History, Budapest, Hungary.

**BPI** -U.S. National Fungus Collections, Beltsville, Maryland, U.S.A.

**CBS** -Centraalbureau voor Schimmelcultures, Baarn, Netherlands.

**CDC** -Centres for Disease Control, Atlanta, Georgia, U.S.A.

**CER** -Cereal agar.

**clavate** -Club-shaped.

**cleistoperidium** -A peridium of one or more layers of flattened cells which forms a continuous envelope around the ascospores and associated ascogenous cells.

**CMI** -Commonwealth Mycological Institute, Kew, England.

**coil** -A spiral or helical hypha, usually formed at the thin-walled, terminal end of an appendage or vegetative cell. It may appear as a series of rings with the LM.

**condylate** -Having or or more rounded processes.

**conglobate** -Refers to ascospores remaining in typical 8-spored clusters after ascus dissolution.

**conidiogenous** -Giving rise to conidia.

**cultura desiccata** -A dried axenic culture.

**DAOM** -National Mycological Herbarium, Ottawa, Ontario, Canada

**DBN** -Herbarium, National Botanic Gardens, Dublin, Ireland.

## GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**deflexed** -Refers tp branches bending away from the main axis at an angle greater than 90°.

**dichotomous** -Refers to branching which occurs in a bifurcate pattern.

**DSA** -Dextrose salts agar with hair.

**E** -Herbarium, Royal Botanic Garden, Edinburgh, Scotland.

**echinulate** -Describing a surface covered with short, tooth-like projections.

**FH** -Farlow Herbarium of Harvard University, Cambridge, Massachusetts, U.S.A.

**FI** -Herbarium Universitatis Florentinae, Museo Botanico, Firenze, Italy.

**fibrillose** -Appearing like a more or less parallel arrangement of fibres.

**form-genus** -A genus based on a part of a fungus other than the teleomorph.

**fruit body** -A general term which may apply to an individual ascoma or any type of aggregation of ascomata such as a stroma, q.v.

**fusiform** -A prolate (or lengthened) sphaeroid, somewhat pointed at the poles (see Table 3.5).

**G** -Herbarium, Conservatoire et Jardin Botanique, Geneva, Switzerland.

**germ pore** -Thin-walled area on the surface of a spore through which a germ tube extends on germination.

**habitat** -Natural place of occurrence of an organism, e.g. dung, soil etc. (cf. substrate).

**HBG** -Herbarium, Institut fur Allgemeine Botanik und Botanischer Garten, Federal Republic of Germany.

**heterothallic** -Sexual reproduction requires an opposite mating type strain.

## GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**holomorph** -The whole fungus including teleomorph and anamorph(s).

**homothallic** -Sexual interaction may occur in the absence of an opposite mating type.

**hymenium** -A layer of meiospore-bearing tissue.

**hyphal peridium** -A general term encompassing all types of non-membranous peridia (see incompositoperidium, reticuloperidium and telaperidium).

**ICBN** -International Code of Botanical Nomenclature.

**incompositoperidium** -A peridium which, at maturity, is reduced to an apparently unorganized, disarticulated mass of thick-walled, contorted cells.

**K** -Herbarium, Royal Botanic Gardens, Kew, England.

**keratinous** -Containing, or consisting in whole or in part of, the protein keratin.

**LE** -Herbarium, Academy of Sciences of the U.S.S.R., Leningrad, U.S.S.R.

**lectotype** -A type selected from the original elements (specimens or names) on which a taxon was based, when there is no holotype to serve as the nomenclatural type (see Article 7 ICBN).

**lenticular** -Shaped like a biconvex lens.

**LM** -Light microscope.

**LPS** -Herbario, Instituto de Botanica "C. Spegazzini," La Plata, Argentina.

**macroconidia** -The large conidia in fungi with two size classes of conidia.

**metulae** -Branches which terminate in cells giving rise to phialidic conidia.

**MICH** -Herbarium of the University of Michigan, Ann Arbor, Michigan, U.S.A.

**microconidia** -The small conidia in fungi with two size classes of conidia.

**monopodial** -A branching pattern with a long main axis with shorter, alternate or bilateral branches.

**MPU** -Institut de Botanique, Universite de Montpellier, France.

**Mycosel** -Trade name of Baltimore Biologicals Inc. for a formulation of dextrose- peptone- cycloheximide- chloramphenicol agar which is an isolation medium for many fungi of medical importance.

**NEB** -University of Nebraska State Museum, Lincoln, Nebraska, U.S.A.

**neotype** -An element (usually a specimen) chosen as nomenclatural type when the original material on which the taxon is based is lost (see Article 7 ICBN).

**NRRL** -Northern Regional Research Laboratory, Pieoria, Illinois.

**NY** -Herbarium, New York Botanical Garden, Bronx, New York, U.S.A.

**NYS** -Herbarium, New York State Museum, Albany, New York, U.S.A.

**O** -Botanical Garden and Museum, University of Oslo, Oslo, Norway.

**O-** -Denotes accession numbers used by G. F. Orr.

**OAT** -Oatmeal agar.

**operculum** -A lid or valve; here referring to the cap over the pore or slit located in the a the tip of the ascus in some ascomycetes.

**OSC** -Herbarium, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, U.S.A.

**ossiform** -Shaped like a bone having a central shaft and swellings on either end (see Table 3.4).

GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**PACA** -Herbarium Anchieta, Instituto Anchietano e Unisinos, Rio Grande do Sul, Brazil.

**PAD** -Istituto di Botanica e Fisologia Vegetale, Orto Botanico, Padova, Italy.

**PAV** -Orto Botanico, Universita di Pavia, Italy.

**PDA** -Potato dextrose agar.

**pectinate** -"comb-shaped"; or having tooth-like projections in a row (see Table 3.4).

**penicillus** -The brush-like arrangement of chains of conidia on the conidiophore of some Eurotialean anamorphs.

**peridium** -A structure more or less enclosing the asci and ascospores.

**petaloid** -Refers here to ascospores which appear to be arranged in the ascus like the petals of a simple radiate flower (see Table 3.5).

**phialide** -A conidiogenous cell which produces conidia from a fixed locus (similar to process of blowing soap bubbles through a ring).

**phialoconidium** -Conidium extruded from a phialide.

**phragmoconidium** -A conidium with two or more cross walls (see Table 3.7).

**plesiomorphic** -Referring to the pre-existing character of an evolutionary transformation series or pair of homologous characters (cf. apomorphic).

**PREM** -National Mycological Herbarium, Pretoria, Republic of South Africa.

**punctate** -Having a surface with small cavities or dents with steep walls (see Table 3.6).

**pyriform** -Pear-shaped.

**punctate-reticulate** -Marked with large regular cavities which are broader than the intervening walls (Table 3.6).

**racquet hypha** -A series of cells each swollen adjacent to one septum.

**reticulate** -Net-like.

**reticuloperidium** -A mesh-like peridium of richly branched and more or less anastomosed, thick-walled hyphae.

**rhexolytic** -Dehiscence of a conidium involving dissolution of the subtending cell(s).

**rhizomorph** -Closely packed, parallel arrangement of hyphae, usually demonstrating some tissue differentiation so that the organ so formed resembles a root of a vascular plant.

**RSA** -Herbarium, Rancho Santa Ana Botanic Garden, Claremont, California, U.S.A.

**S** -Herbarium, Swedish Museum of Natural History, Stockholm, Sweden.

**SAC** -Single ascospore culture.

**schizolytic** -Dehiscence (secession) by fission through a double septum separating a conidium and a conidiogenous cell or two adjacent conidia.

**SEM** -Scanning electron microscope.

**seta** -Specialized, stiff, often pointed or uncinate hypha produced in association with conidia.

**sinuate** -Wavy.

**species** -A self-perpetuating genetic line which propagates itself more or less independently of other such lines and is usually morphologically recognizable.

**striate** -Marked by fine parallel grooves.

**stroma** -A conglomeration of ascomata within a mass or matrix of cells derived from more or less differentiated hyphae.

**substrate** -Specific material on which or in which a saprobe is living e.g. cellulose, keratin (see also habitat).

**sulcate** -Grooved.

**synanamorph** -One of two or more anamorphs which belong to the same teleomorph.

**tapered** -Referring to the terminal end of an appendage where there is a gradual decrease in wall thickness, pigmentation and diameter.

**telaperidium** -A mesh-like peridium of thin-walled hyphae lacking any obvious differentiation from the vegetative hyphae.

**teleomorph** -The morphological phase of the life cycle of a fungus in which meiospores are produced. cf. anamorph.

**thallic** -Describes a conidium which differentiates within the parent hypha after septation at one or either end.

**trichogyne** -An elongated hypha serving as the receptive ("female") cell in some ascomycetes.

**TRTC** -Cryptogamic Herbarium, Department of Botany, University of Toronto, Toronto, Ontario, Canada.

**tuberculate** -Describing a surface covered with tubercles or blunt spines (see Table 3.4).

**type strain** -A culture derived by axenically propagating material isolated from the type collection of a taxon. Not a nomenclatural type.

**U** -Institute for Systematic Botany, Utrecht, Netherlands.

**UADBG** -University of Alberta Devonian Botanic Garden, University of Alberta, Edmonton, Alberta, Canada.

GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

**UAMH** -University of Alberta Mold Herbarium and Culture Collection, Edmonton, Alberta, Canada.

**uncinate** -Shaped like a rounded hook.

**undulate** -Having wave-like markings on the surface (see Table 3.6).

**UPS** -Herbarium, University of Uppsala, Uppsala, Sweden.

**UV** -Ultra-violet radiation.

**VER** -Erbario Generale del Museo Civico di Storia Naturale, Verona, Italy.

**verrucose** -Covered with wart-like projections.

**WIS** -Herbarium, Department of Botany, University of Wisconsin, Madison, Wisconsin, U.S.A.

# CHAPTER 1

## INTRODUCTION

### Background and Objectives of this study

The majority of fungi grow on higher plants or their remains. The Gymnoascaceae and Onygenaceae are unusual in that most of them are associated with birds or mammals. They include the only true fungi that vigorously degrade keratin, as well as several of the most important human pathogenic fungi. Members of these families are also common in the dung of birds and other animals, (especially carnivores), and in soil enriched with dung or keratinous debris. In addition to the keratinophils, some of the species traditionally included in the Gymnoascaceae are cellulolytic, while still others attack neither cellulose nor keratin.

Soil surveys for keratinolytic fungi, carried out at the University of Alberta Mold Herbarium and Culture Collection from 1956 through 1969, yielded many cultures of gymnoascaceous/onygenaceous fungi. From 1961 to 1975, G. F. Orr sent UAMH several hundred cultures from soil or dung for deposit or identification. Many other workers have sent smaller numbers of keratinophilic fungi for identification. The anamorphs of some of these collections have been carefully studied and monographed (Carmichael, 1962; Padhye and Carmichael, 1971a; Sigler and Carmichael, 1976; Van Oorschot, 1980). The teleomorphs have proved more difficult to organize. Despite descriptions of numerous taxa by Apinis (1964); Apinis and Clark (1964); Kuehn (1960), Kuehn and Orr (1959, 1963); Orr (1970, 1976, 1977a,b,c); Orr and Kuehn (1964); Orr, Kuehn and Plunkett (1963a,b,c); Orr, Roy and Ghosh (1977); and other workers, no one has surveyed specimens and cultures of the entire group to clearly delimit the species, genera and families.

There have been a number of taxonomic revisions of parts of the Gymnoascaceae, based on the literature or the study of a few representatives (Apinis, 1964; Orr, Ghosh and Roy (1977); Samson, 1977; Von Arx, 1971, 1977). However, none of the revisions was comprehensive and, unfortunately, they frequently disagreed with each other regarding important taxonomic characters and in the description and delimitation of taxa. The Onygenaceae has

received much less attention (Malloch and Cain, 1971a,b; Rammeloo, 1982) and in spite of numerous suggestions of relationship to the Gymnoascaceae (Fennell, 1973; Malloch, 1981; Matruchot and Dassonville, 1899), a detailed comparative study has never been undertaken.

In order to sort out the confusion and apply meaningful names to the cultures in UAMH, it was obviously necessary to review the entire literature on the group and to study and compare as many specimens as possible, both from UAMH and other collections. After some preliminary investigation, three objectives were established for this study: 1. to compile published information on all named taxa and produce an annotated list similar to the list of form-genera in Carmichael *et al.*, 1980; 2. to examine and compare as many representatives as possible, both from existing collections and from new isolations;and, 3. to determine reasonable limits for the species, genera and families, and to provide descriptions, illustrations and pictorial tables to aid in identification.

The results of this study are presented in the following order: first, an historical review of the literature on the taxonomy of the Onygenaceae and Gymnoascaceae and an explanation of the development of the concept of the Onygenales as it is used here (Chapter 1); second, materials and methods (Chapter 2); third, a discussion of the disposition of the order with respect to other Plectomycetes, an evaluation of the use of morphological characters in taxonomy, some ecological and evolutionary aspects of the order, and a key to the families (Chapter 3); fourth, annotated lists of the taxa in each of the four families recognized (Chapters 4, 5, 6 and 7). The genus *Gymnascella* (and its allies) were studied in relatively greater detail, but these are presented in context to maintain continuity and reduce repetition. Finally, there is an annotated list of excluded genera, a list of references cited, and an index to taxa.

**Historical survey of the Gymnoascaceae and Onygenaceae**

Taxonomic concepts in the Gymnoascaceae and Onygenaceae have developed independently. Apparent remoteness of the two groups is due to the strikingly different morphology of the types of each family (see *Gymnoascus reessii*, PL 5.8d and *Onygena equina*, PL 7.12d). Although *Onygena* predates *Gymnoascus* by

23 years, the historical aspects of the Gymnoascaceae are discussed first since it has become the largest and most studied of the two groups.

Gymnoascaceae

Since the description of *Gymnoascus* and the definition of the Gymnoascaceae by Baranetzky in 1872, the characteristics and consequent membership or scope of the family have been repeatedly debated. Baranetzky's definition for the group (1872) was the absence of a complete peridium enclosing the asci. This simple criterion served to include in one group *Endomyces*, *Saccharomyces*, *Taphrina*, and *Gymnoascus*.

In 1880 Eidam reviewed Baranetzky's Gymnoascaceae and removed *Saccharomyces* and *Endomyces*, arguing that their characteristics supported a closer relationship to other fungal groups (phycomycetes!). To the remaining taxa (*Taphrina* and *Gymnoascus*) he added his new genus *Ctenomyces* and created two subfamilies based on trophic characters: parasitic gymnoascaceae, including those which formed in leaves and fruits (*Ascomyces*, *Taphrina*, and *Exoascus*); and saprophytic gymnoascaceae, including the coprophilous genera *Ascodesmis* and *Gymnoascus*. He noted that *Ascomyces*, *Ascodesmis*, *Exoascus* and *Taphrina* appeared to be closer to the discomycetes and *Gymnoascus* to the pyrenomycetes.

Brefeld (1891) denied family relationship among Eidam's Gymnoascaceae, and placed *Gymnoascus* in his "Carpoasci" and *Ascomyces* and *Taphrina* in the "Exoasci." These two major groups represented a major division of all the ascomycetes known at that time.

Schroeter (1893) redefined the family to include simple cleistothecial ascomycetes with a peridium of loosely differentiated hyphae surrounding the ascogenous tissue. Within this definition, he included 5 genera: *Amauroascus*, *Arachniotus*, *Ctenomyces*, *Gymnoascus*, and *Myxotrichum*.

Massee (1895) stated his support for a broader family concept, characterized by the total lack of peridial structure and reinstated *Ascodesmis*, *Ascomyces* and *Taphrina* in the Gymnoascaceae, although the latter 2 genera were given subfamily status.

Concluding developments in the 19th century, Matruchot and Dassonville

(1899) followed Schroeter and Brefeld in part while maintaining a broad definition for the family. They divided the Gymnoascaceae into 3 tribes (a procedure that was to be repeated with different emphases several times during the next century): Endomycetees: (*Endomyces*); Onygenees: (*Onygena*); and Gymnoascees (*Ctenomyces, Gymnoascus, Microsporum, Trichophyton* and *Achorion*). (The last 3 genera were included on the basis that asci were formed under some circumstances).

Clements and Shear (1931) proposed the new order Gymnascales, which was characterized by: "the free ascus or ascus-group, without protective hyphae or these limited to a loose or dense mass." The order included the Endomycetaceae, Schizosaccharomycetaceae, and Monascaceae, as well as the Gymnoascaceae. In the Gymnoascaceae they placed *Amauroascus, Arachniotus, Conidiascus, Ctenomyces, Diplostephanus, Eidamella, Gymnoascus, Hexagonella, Lilliputia, Myrillium, Myxotrichum, Penicilliopsis* and *Rollandina*.

Table 1.1 should be referred to, during the following discussion of recent taxonomic treatments of the Gymnoascaceae. Benjamin (1956) modified Schroeter's (1893) family concept by providing more detailed information on the characteristics of the ascoma . He characterized the family as follows:

> "Ascocarps [ascomata] roundish, usually a cleistoperidium consisting of a lax network of interwoven often anastomosed, thin or thick-walled hyphae surrounding the ascigerous tissue, or rarely the latter devoid of a special hyphal investment. Peridial hyphae, when present, smooth-walled or roughened, simple or giving rise to variously modified branches or appendages. Asci irregularly disposed, globoid to pyriform, 8-spored, wall evanescent. Ascospores one-celled, globose, oblate, ovoid, or lenticular, smooth or sculptured. Asexual reproduction by conidia or chlamydospores."

He included in his review: *Amauroascus, Arachniotus, Arthroderma, Byssochlamys, Ctenomyces, Eidamella, Gymnoascus, Myxotrichum, Pseudogymnoascus*, and a new genus, *Shanorella*. He excluded a number of genera listed by Clements and Shear (1931). (*Carpenteles, Conidiascus, Diplostephanus, Hexagonella, Lilliputia, Myrillium, Penicilliopsis*, and *Rollandina*. See Chapter 8, Excluded Genera).

Shortly after Benjamin's revision, Kuehn (1958, 1959) published a survey of the family which included his new genus *Pseudoarachniotus*. He circumscribed the family in essentially the same way as Benjamin. In neither treatment was any emphasis placed on the mode of conidiogenesis. The family, according to

**TABLE 1.1**

SUPRAGENERIC GROUP NAMES USED FOR GYMNOASCACEOUS GENERA BETWEEN 1956 AND 1980.

| | | |
|---|---|---|
| Benjamin 1956 | | Gymnoascaceae |
| *Amauroascus* | *Arachniotus* | *Arthroderma* |
| *Byssochlamys* | *Ctenomyces* | *Eidamella* |
| *Gymnoascus* | *Myxotrichum* | *Pseudogymnoascus* |
| *Shanorella* | | |
| Kuehn 1958, 1959 | | Gymnoascaceae |
| *Amauroascus* | *Arachniotus* | *Arthroderma* |
| *Byssochlamys* | *Ctenomyces* | *Eidamella* |
| *Gymnoascus* | *Myxotrichum* | *Pseudoarachniotus* |
| *Pseudogymnoascus* | *Shanorella* | |
| Apinis 1964 | | Gymnoascaceae |
| Arachnoideae | Arthrodermoideae | Gymnoascoideae |
| *Amauroascus* | *Arthroderma* | *Actinodendron* |
| *Arachniotus* | *Ctenomyces* | *Gymnoascus* |
| | *Shanorella* | *Myxotrichum* |
| Benny and Kimbrough 1980 | | Gymnoascaceae |
| Arachnoideae | Arthrodermoideae | Gymnoascoideae |
| *Amauroascus* | *Ajellomyces* | *Auxarthron* |
| *Arachniotus* | *Apinisia* | *Ctenomyces* |
| *Arachnotheca* | *Arthroderma* | *Gymnoascus* |
| *Byssoascus* | *Nannizzia* | *Myxotrichum* |
| *Narasimhella* | *Shanorella* | *Pectinotrichum* |
| *Renispora* | *Spiromastix* | *Pseudogymnoascus* |

Benjamin and Kuehn, had anamorphs producing "oidia, chlamydospores, or conidia." Indeed, Benjamin stated, "What significance if any, is to be attached to the imperfect stages [anamorphs] encountered in the Gymnoascaceae is not apparent."

In 1964, Apinis published a revision of the family restricting his treatment to species which had been found in Britain. He excluded *Byssochlamys* due to the penicillate conidiophores with phialidic conidiogenesis, and was the first worker in the group to attach significance to the mode of conidiogenesis. He presented a rather conservative approach to the group and formally described three subfamilies separated on characteristics of the peridial elements and appendages: Gymnoascoideae, which included *Gymnoascus* (in which genus he included as subgenera *Auxarthron* and *Pseudogymnoascus*), *Myxotrichum* and *Actinodendron*; Arthrodermoideae, *Arthroderma*, *Ctenomyces*, *Nannizzia* and *Shanorella*); and Arachnoideae, (*Amauroascus* and *Arachniotus*).

No attempt was made to correlate peridium features with other morphological characteristics such as ascospore shape and ornamentation, even though variations in these characters had been noted in his treatment.

Benny and Kimbrough (1980) also treated the Gymnoascaceae in 3 subfamilies, separated on the basis of characteristics of peridial hyphae. Their system more or less coincided with Apinis' treatment. The Arachnoideae included *Amauroascus*, *Arachniotus*, *Arachnotheca*, *Byssoascus*, *Renispora*, and *Narasimhella*. *Ajellomyces*, *Apinisia*, *Arthroderma*, *Nannizzia*, *Shanorella*, and *Spiromastix* were placed in the Arthrodermoideae. *Auxarthron*, *Ctenomyces*, *Gymnoascus*, *Myxotrichum*, *Pectinotrichum* and *Pseudogymnoascus*, because of their highly differentiated peridial hyphae, were placed together in the Gymnoascoideae. As in the subfamily system of Apinis no consideration of ascospore morphology was included.

<u>Onygenaceae</u>

The Onygenaceae, (typified by *Onygena*) was proposed by Fries in 1849 to contain stipitate cleistothecial ascomycetes. Fischer (1897) placed the Onygenaceae in the Gymnoascales close to the Gymnoascaceae. Clements and Shear (1931) placed the family in the Tuberales with the Elaphomycetaceae and

Tuberaceae (truffles). They considered the Onygenaceae to include three genera: *Dendrosphaera*, *Onygena* and *Trichocoma*. Boedijn (1935) revised the family to include three monogeneric subfamilies: Dendrosphaeroideae (*Dendrosphaera*); Onygenoideae (*Onygena*); and Trichocomoideae (*Trichocoma*). These subfamilies were raised in rank to families within the new order Onygenales by Ciferri in 1957. Table 1.2 summarizes organization of Onygenaceous genera from 1957 (Fennell's (1973) treatment is excluded). Malloch and Cain (1971) revised the family definition to exclude stipitate cleistothecial ascomycota that had phialidic or annellidic anamorphs, thereby removing *Dendrosphaera* and *Trichocoma*. Their description of the Onygenaceae (1971) follows.

> "Onygenaceae Fr., Summa Veg. Scan. 2:446, 1849
> Mycelium hyaline, often with ampulliform swellings. Ascocarp initials consisting of large prominent coils or swollen cells. Ascocarps variously shaped, stipitate or sessile, hyaline or light colored, never dark brown or black, glabrous to hairy or tomentose or variously appendaged, nonostiolate, frequently varying greatly in size within the same collection. Asci subglobose to globose, irregularly disposed, nonstipitate, evanescent, usually arising from prominent croziers. Ascospores one-celled, hyaline to brightly colored, never dark brown to black, variously shaped, often oblate, smooth to roughened or ridged, with equatorial ridges in some genera, always lacking germ pores. Conidial stages produced as arthroconidia or aleurioconidia, never as phialospores or annelospores. Conidia hyaline, one- to several-celled, smooth or roughened. Frequently occurring on keratinous substrates, but also on dead plant debris and soil."

Using the above criteria they were able to include: *Arachnomyces*, *Ascocalvatia*, *Aphanoascus* (in which they included *Keratinophyton*), *Dichotomomyces*, *Onygena*, and *Xynophila*. *Pleuroascus* was added in 1973 (Malloch and Benny, 1973).

Fennell's (1973) concept also considered the Onygenaceae as cleistocarpous Gymnoascaceae occurring frequently on keratinous substrates. She summarized their morphological characteristics as follows:

> " ascocarp initials (unknown in *Onygena*) consisting of coiled ascogonia; ascomata usually spherical, stipitate or sessile, red brown to brown, peridium membranous, with or without appendages; asci arising from croziers. Conidial states arthroconidia and aleurioconidia."

With respect to the "unknown" initials, Gaumann (1929) reported that at multiple sites within the "head" of the *Onygena* fruiting bodies, coils "superficially like *Penicillium* form and give rise to the ascospores." These coils were illustrated (Gaumann, 1928, FIG 118, 3, p187). Malloch (1981) also suggested multiple ascogonial initials in *Onygena*. *Xylogone*, which had been included in the Onygenaceae by von Arx and Nilsson (1969) was placed in the Monascaceae

**TABLE 1.2**

GENERA ASSOCIATED WITH THE SUPRAGENERIC NAMES RELATED TO THE GENUS *Onygena* BETWEEN 1957 and 1980

| Ciferri 1957 | | Onygenales |
|---|---|---|
| Dendrosphaeraceae | Onygenaceae | Trichocomaceae |
| *Dendrosphaera* | *Onygena* | *Trichocoma* |
| **Malloch and Cain 1971b** | | **Onygenaceae** |
| *Aphanoascus*<br>*Dichotomomyces*<br>*Xynophila* | *Arachnomyces*<br>*Onygena* | *Ascocalvatia*<br>*Thermoascus* |
| **Benny and Kimbrough 1980** | | **Onygenales** |
| Dendrosphaeraceae | Gymnoascaceae | Onygenaceae |
| *Dendrosphaera* | *Ajellomyces*<br>*Amauroascus*<br>*Apinisia*<br>*Arachniotus*<br>*Arachnotheca*<br>*Arthroderma*<br>*Auxarthron*<br>*Byssoascus*<br>*Ctenomyces*<br>*Gymnoascus*<br>*Myxotrichum*<br>*Nannizzia*<br>*Narasimhella*<br>*Pectinotrichum*<br>*Pseudogymnoascus*<br>*Renispora*<br>*Shanorella*<br>*Spiromastix* | *Anixiopsis*<br>*Arachnomyces*<br>*Ascocalvatia*<br>*Dichotomomyces*<br>*Diehliomyces*<br>*Neoxenophila*<br>*Onygena*<br>*Pleuroascus*<br>*Thermoascus*<br>*Xanthothecium*<br>*Xylogone*<br>*Xynophila* |

"arbitrarily" with a note that its taxonomic disposition might well be made elsewhere. Fennell (1973) separated the Monascaceae from the Gymnoascaceae on the basis of the former having a peridium of flattened cells; and from the Eurotiaceae on the basis of arthroconidium production. She did not suggest a distinction between Onygenaceae and Monascaceae. *Thermoascus* and *Dichotomomyces* were not included in her Onygenaceae as they were in Malloch and Cain's treatment (1971a), but placed in the Thermoascaceae (Apinis, 1967) and Eurotiaceae (Clements and Shear, 1931) respectively. Neither did she consider *Ascocalvatia* or *Xynophila*, although she was apparently aware of their existence.

While studying a variety of reduced or yeast-like fungi, Redhead and Malloch (1977), referred their new genus *Galactomyces* (which included *Endomyces geotrichum* Butler and Petersen, (1972) and *Endomyces reessii* van der Walt (1959) to their expanded concept of the Onygenaceae. They supported the disposition of *Galactomyces* in the Onygenaceae, using the evidence that *Geotrichum candidum* Link (arthroconidial state of *Endomyces geotrichum*) is associated with milk and other animal exudates and produces "ascospores with an equatorial groove."

Malloch (1979), in a consideration of the resemblance of the anamorphs of members of Gymnoascaceae to those of the Onygenaceae, suggested that one family should encompass nearly all the genera included to date. Stating that the most characteristic feature of the new family concept was that conidia are never "enteroblastic" but "holoblastic" or "thallic," he suggested that there were about 30 genera but did not list them. *Myxotrichum* and taxa with "dark-colored" cleistothecia were tentatively, and with some reservation, placed in the Pseudoeurotiaceae.

In a discussion of the putative families of the Pezizales, Malloch (1981b) described the Gymnoascaceae as differing from the Onygenaceae only in the nature of the peridium and again suggested that Onygenaceae could encompass the genera of both families.

Benny and Kimbrough (1980), again reviewed the genera of the Onygenaceae, essentially reiterating Malloch's (1971) definition. In addition to *Onygena*, 13

genera were included: *Arachnomyces, Ascocalvatia, Anixiopsis, Dichotomomyces, Diehliomyces, Keratinophyton, Leucothecium, Neoxenophila, Pleuroascus, Thermoascus, Xanthothecium, Xylogone,* and *Xynophila.*

The bifurcate conidiophore of *Dichotomomyces* has been illustrated by Tubaki (1981) as annellidic rather than holoblastic as originally supposed and the genus may therefore be removed from the Onygenales. *Diehliomyces* was a new addition to the family.

**Concept of the Onygenales**

Family concepts have placed tremendous emphasis on characters of the peridium and indeed, the final distinction between the two families is based on whether or not the peridium is complete, or mesh-like or absent. This has obscured the importance of other characters such as ascospore morphology, nature and occurrence of anamorphs, and enzymatic capacities, which contain significant information for making a classification of the fungi traditionally treated in the two families. Various workers have suggested independently that the Onygenaceae and Gymnoascaceae might best be accommodated in one taxonomic unit (e.g. Von Arx, 1981). Alexopoulos and Mims (1980), Barr (1983), Benny and Kimbrough (1980), and Eriksson (1982a,b) have suggested that the Onygenales encompass both the Gymnoascaceae and Onygenaceae. A close relationship between the two families has been suggested since 1899, when Matruchot and Dassonville combined them within the Gymnoascaceae. Recently, one-family status for the group was again suggested by Malloch (1980) who considered the Onygenaceae (including the Gymnoascaceae) in the Pezizales.

While, in principle, work reported here agrees with placing the two families in the order Onygenales, my observations would indicate that the families (and subfamilies) as they have been traditionally defined are extremely heterogeneous.

It is a well established observation that keratinous materials are frequent sites of collection for the group. Many representatives will degrade keratin supplied in culture (English, 1963a,b; Safranek and Goos, 1982). Some members cannot degrade keratin, but will degrade cellulose and/or other non-keratinous compounds. The significance of these contrasting enzymatic capabilities is obscured by the extant classification, since traditional genera, based on peridium

characters, contain both keratin-degrading and non keratin-degrading species, e.g. *Gymnoascus uncinatus* and *Gymnoascus reessii*; *Amauroascus niger* and *Amauroascus echinulatus*. If this classification is maintained it must be accepted that keratin degradation is of taxonomically limited usefulness, since it does not correlate with morphological characteristics of the peridium.

Keratin degradation involves rupturing the disulphide linkages between the peptide chains of the keratin molecule. This ability is not widespread in the fungi and only occurs in the Gymnoascaceae, Onygenaceae (and Cephalothecaceae if we follow Apinis (1968) in placing *Aphanoascus* in this family) and in some hyphomycete taxa with rhexolytically dehiscing conidia. It also occurs in some chytrids (Karling, 1946) and in some actinomycete species (e.g. *Streptomyces* (Davis *et al*., 1973. Within the filamentous fungi, enzymes able to break the disulphide bridge of keratin molecules probably arose once and their presence among taxa should indicate a high level of relationship. This premise is given weight when it is considered that sexually reproducing fungi with this characteristic, almost without exception, demonstrate a unique pattern of puncta on the ascospore wall.

The exceptions to this correlation may be found in the smooth-spored genera *Arthroderma*, *Nannizzia* and *Ctenomyces* which exhibit pronounced specializations in habitat. The last genus is quite often found on feathers and the first two are either pathogens or devoted saprophytes of products of mammal origin. These three genera are included here in the family Arthrodermataceae and besides having smooth, minute, oblate ascospores, also generally produce large, multiseptate conidia (phragmoconidia) (*Ctenomyces* excepted). They are also almost uniformly heterothallic.

Keratin digestion and punctate ascospores as correlated characters occur throughout a spectrum of peridial types from almost absent (in culture) in *Amauroascus*; to hyphal in *Auxarthron* and *Pectinotrichum*; to membranous in *Xynophila* and *Aphanoascus*. Further uniting these taxa are anamorphs with alternate and terminal, rhexolytically dehiscing arthroconidia. The keratinolytic species with reticulate or punctate ascospores are, in this treatment, placed in the Onygenaceae.

With these taxa excluded, non-keratinolytic species with reticulothecia or with more or less naked clusters of asci, remain. Within this group, anamorphs occur less often, although those which are found continue to be thallic types similar to those of the previous group.

From this assemblage, *Myxotrichum*, (*Byssoascus* and *Pseudogymnoascus*) emerge as comprising an identifiable group. These taxa have reddish brown, thick-walled peridial hyphae, strong cellulolytic capacities and either a simple or dendritic arrangement of alternate, or terminal, rhexolytically dehiscing arthroconidia. Ascospores are hyaline to pale yellow or rose, distinctively fusiform and either striate or smooth. These fungi are placed in a new family, the Myxotrichaceae. Within this family there are taxa which have reduced (or absent) peridia as well as taxa with well-developed, and elaborately appendaged reticuloperidia. Von Arx (1981b) has also suggested family status for these taxa.

Remaining is a heterogeneous assemblage of taxa which have a questionable degree of relationship. This group, assigned here to the Gymnoascaceae, is typified by *Gymnoascus* and includes *Acitheca*, *Arachniotus*, *Gymnascella*, *Gymnoascoideus* and *Gymnoascus*. A more appropriate disposition of some of these taxa might well be in the Eurotiales rather than in the Onygenales. The Gymnoascaceae has smooth, mostly oblate ascospores, reduced peridia or reticuloperidia, and does not exhibit strong substrate preferences. Members are neither keratinolytic nor markedly cellulolytic. Anamorphs have not been recorded for many species.

The Onygenales then, may be circumscribed as follows:

**Onygenales** Ciferri ex Benny and Kimbrough, 1980, em. Currah and Carmichael.

**Ascomata:** discrete or confluent, naked or within a more or less specialized secondary structure, which may be sessile or stipitate; generally small, white, or pale cream, orange, reddish brown; non-ostiolate. **Ascospores:** small, mostly 3-5*u*m or less in diam., and none larger than 8*u*m at greatest diam., single-celled, lacking germ pores, hyaline to pale in color (yellow, green, tan, brown); smooth, punctate, or punctate-reticulate (may appear spiny with LM), undulate, or striate; globose, oblate, discoid, fusoid or allantoid in shape. **Asci:** membrane quickly evanescent, ascospores usually conglobate (adhering in groups

of 8, rarely fewer); asci globose, ovoid or petaloid in shape. **Peridium:** peridium absent or scarcely differentiated; to mesh-like and composed of thick-walled smooth, asperulate or tuberculate hyphae; to membranous; hyaline or colored (yellow, orange, tan, reddish brown, brown). **Appendages:** absent or well-developed, simple to highly differentiated, usually thick-walled, smooth or tuberculate. **Ascocarp initials:** short coils, usually with a central club-shaped cell ("antheridium") surrounded by a coiled, elongate hyphal branch ("ascogonium"); homothallic or heterothallic. **Anamorph:** absent, or producing hyaline to pale aleurioconidia or arthroconidia, all with rhexolytic dehiscence. **Habitat:** soil, dung, plant debris, paper or processed materials containing cellulose, lichen thalli. Some parasitic on mammals, others associated with birds; frequent on both keratinous and non-keratinous materials of animal origin or materials associated with animals.

Four families are included in the Onygenales: Arthrodermataceae, Gymnoascaceae, Myxotrichaceae and Onygenaceae. These are presented in a pictorial key (Table 1.3) and discussed in detail in Chapter 3. The genera are listed alphabetically by family in Table 1.4.

TABLE 1.3

FAMILIES OF THE ONYGENALES

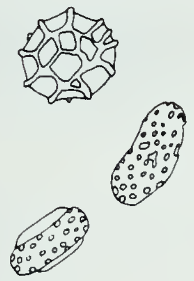
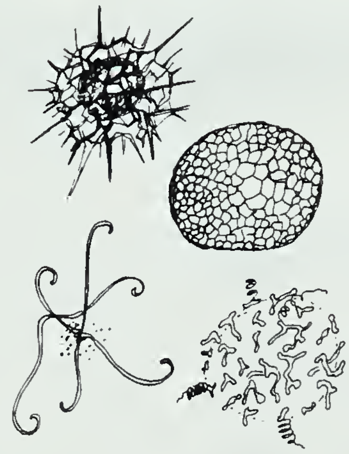
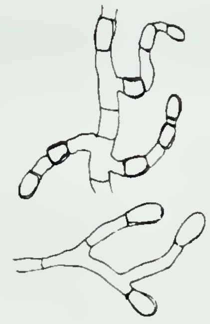
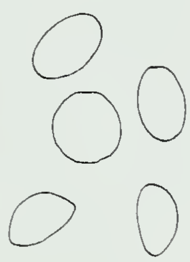
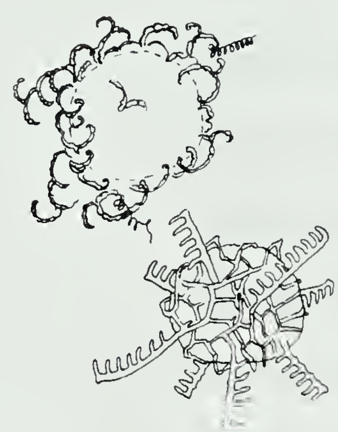
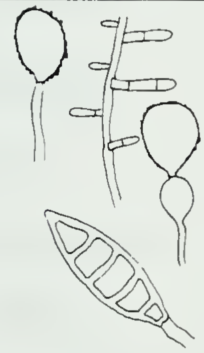
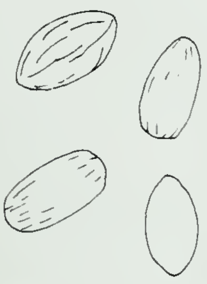
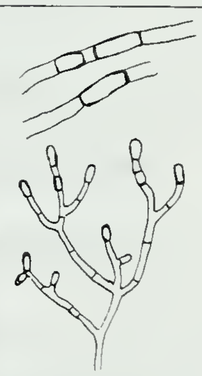
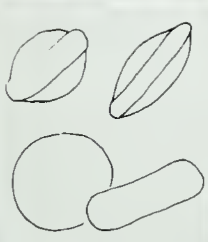
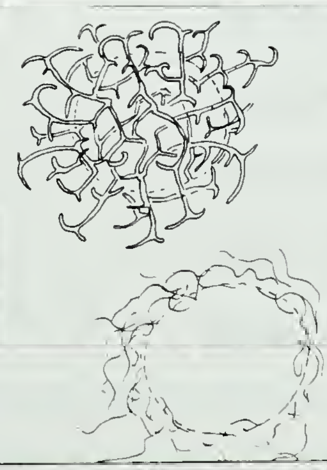
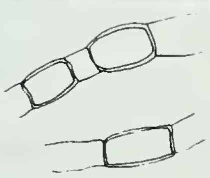
| Family | Ascospores | Peridia and Appendages | Anamorphs | Substrate* and Habitats |
|---|---|---|---|---|
| ONYGENACEAE |  pitted; spherical, oblate, allantoid. |  |  CHRYSOSPORIUM<br>MALBRANCHEA<br>SPORENDONEMA | carnivore dung<br>soil enriched with keratin or dung<br>**KERATIN*** |
| ARTHRODERMATACEAE |  smooth; oblate to oblate-discoid or oblate-convex. |  |  CHRYSOSPORIUM<br>MICROSPORUM<br>TRICHOPHYTON | decaying hoof, horn, feathers, hair and skin<br>some are parasitic on animals |
| MYXOTRICHACEAE |  smooth or striate; fusiform, ellipsoid. |  |  GEOMYCES<br>MALBRANCHEA<br>OIDIODENDRON | processed or decaying plant materials<br>**CELLULOSE***<br>paper, straw, soil around the roots of plants |
| GYMNOASCACEAE |  smooth or slightly irregular ("lumpy"); often with polar and/or equatorial thickenings. |  |  absent or of un-named arthroconidia. | decaying vegetation<br>soil rich in organic matter<br>**VARIABLE***<br>various types of dung |

TABLE 1.4

GENERA OF THE ONYGENALES LISTED ALPHABETICALLY ACCORDING TO THE FAMILY SYSTEM USED IN THIS THESIS

| Arthrodermataceae | Onygenaceae |
|---|---|
| *Arthroderma* | *Ajellomyces* |
| *Ctenomyces* | *Amauroascus* |
| *Nannizzia* | *Aphanoascus* |
| | *Apinisia* |
| Gymnoascaceae | *Ascocalvatia* |
| | *Auxarthron* |
| *Acitheca* | *Keratinophyton* |
| *Arachniotus* | *Kuehniella* |
| *Gymnascella* | *Nannizziopsis* |
| *Gymnoascoideus* | *Neogymnomyces* |
| *Gymnoascus* | *Neoxenophila* |
| | *Onygena* |
| Myxotrichaceae | *Pectinotrichum* |
| | *Renispora* |
| *Byssoascus* | *Shanorella* |
| *Myxotrichum* | *Spiromastix* |
| *Pseudogymnoascus* | *Uncinocarpus* |
| | *Xynophila* |

# CHAPTER 2

## MATERIALS AND METHODS

Materials were obtained from the University of Alberta Mold Herbarium and Culture Collection (UAMH), other herbaria (listed below), and field collections made between 1980 and 1983 from soil, dung and nest materials found in Alberta. Methods of observation varied with the nature of individual collections.

### Herbarium survey

Herbarium accessions in UAMH consisted of cellophane mounts (Carmichael, 1963) of cultures grown on agar plates of several types of media including one or more of the following: Cereal Agar (CER), Oatmeal Agar (OAT) [=Weitzman and Silva-Hutner, 1967; 'Medium E'], Potato Dextrose Agar (PDA), Phytone Yeast Extract Agar (PYE), (Padhye *et al.*, 1973); and Dextrose Salts Agar with hair (DSA), (Carmichael, 1962). These dried colonies were examined for color, texture, zonation and/or other growth patterns characteristic of the mycelial mat. Reverse coloration (through the cellophane) was also recorded. In all cases, data were referenced to the age of the mycelial mat and the temperature at which it was grown. Since most UAMH collections are routinely illustrated with *camera lucida* drawings and/or photomicrographs, details from these sources were also recorded. For morphological examinations, and to assist in the preparation of drawings and photographs, fresh slides from dried cellophane-backed material were made in lactofuchsin (Carmichael, 1955) and/or glycerin jelly (Ainsworth and Bisby, 1971) and examined with the oil immersion objective of the light microscope.

Ability to degrade keratin was based on amount of digestion of human hair on DSA (Carmichael, 1962). Cellulolytic abilities were determined by the extent of digestion and/or weakening of the cellophane film of herbarium preparations.

The "In culture" part of each description is based on a single strain chosen for each species. However, all UAMH accessions for each species were examined at least briefly and any marked variation is mentioned.

The following herbaria also supplied material for this study: AMD, BP, BPI, DAOM, DBN, E, FH, FI, G, HBG, K, LE, LPS, MICH, MPU, NEB, NY, NYS, O, OSC, PACA, PAD, PAV, PREM, RSA, S, TRTC, U, UPS, VER, and WIS.

Specimens from these institutions varied greatly in nature. Culture discs were examined as for UAMH accessions. Frequently, material consisted of dried samples of dung, paper, hoof, horn, feathers etc., with or without an indication as to where the fungus listed on the packet was situated. On most natural materials, structures of other fungi were present. In mixed collections, only the sexual state was recorded. Where quantities were sufficient, glycerine jelly mounts were prepared.

**Cultural studies**

Only *Gymnascella* isolates were studied comparatively in fresh cultures made specifically for this study. Observations were confined to growth on cellophane on PDA at 25°C. PDA was the medium of choice for several reasons. Most UAMH cultures of *Gymnascella* had not been grown on this medium and most original descriptions were based, at least in part, on characteristics on PDA. Not only is the medium in widespread use, but it also enhances pigment production, an important taxonomic character. Growth rate, as days from inoculation to total plate coverage, color, texture, and presence or absence of diffusible pigments, were the cultural characters recorded.

Microscopic observations of vegetative hyphae, ascomatal initials and features of the ascoma were made by preparing lactofuchsin mounts for examination with the oil immersion objective of the light microscope (LM). Phase contrast microscopy was found to be unsuitable for the examination of thick-walled, refractive structures, such as ascospores, since minute wall irregularities were obscured. Phase was useful for examination of thin-walled conidia, where refractive indices of wall material and mounting medium were similar.

**Isolation from Alberta substrates**

Three methods were used for making primary isolations. The first involved suspending approximately 1 gm of ground source material (usually soil or dung) in 1 l distilled water. Five ml of the suspension were pipetted onto plates of Mycosel and these were incubated at 25°C in the dark for 4 months, during which time they were examined periodically for teleomorphs. This technique was useful for obtaining *Auxarthron* species and anamorphs of various fungi. Second, samples of soil from the vicinity of animal burrows were placed in

sterile petri dishes, moistened, baited with autoclaved human hair and incubated as above. These preparations yielded exclusively isolates of *Arthroderma* or anamorphs assignable to the Arthrodermataceae. Third, samples (usually of dung) were incubated at room temperature in moist chambers (Malloch, 1981a). This technique yielded the greatest number and diversity of onygenalean fungi. Direct isolation with all 3 methods was sometimes successful in securing desired taxa in pure culture, but occasionally serial transfers were necessary. In most cases, whether pure cultures were obtained or not, a permanent slide (glycerine jelly) was prepared from the natural substrate.

**Scanning electron microscope procedures**

Scanning electron microscope (SEM) procedures involved dusting air-dried material from herbarium collections on stubs coated with an adhesive ("microstik," Ted Pella, Inc., California). A coating of gold was then applied with either a Nanotech or Edwards sputter coater. Stubs were examined with a Cambridge S-250 SEM and photographed.

**Development and format of descriptions of taxa**

Concepts of taxa

The species is defined here as a group of morphologically similar individuals representing a genetic line, which propagates itself more or less independently of other such lines (Carmichael *et al.*, 1980). The species I have recognized in the Onygenales are all morphologically distinct from each other except for some in *Arthroderma* and *Nannizzia*. Chief among my criteria are differences in ascospore morphology. Species with similar ascospores (e.g. *Gymnascella aurantiaca*, *G. afilamentosa*, *G. citrina*) are recognized by the discontinuity of such characters as ascospore arrangement within the ascus, ascospore shape and color. Species in the genus *Auxarthron* are chiefly delimited on the basis of peridial characters, which are stable and, consequently, reliable. Close inspection of ascospore morphology yields information which compliments separations based on peridial morphology for the species of *Auxarthron*.

Genera are recognized by a sudden discontinuity, first in ascospore shape and ornamentation, and second, in peridial morphology. Generic descriptions are circumscriptions of similar species.

Families are groups of genera which share degradative capabilities and a common type of ascospore sculpturing (and shape). I have not used peridial morphology to delimit families.

Scope and limitations of descriptions

Descriptions were compiled from the original publication of the names and checked against later treatments in the literature. In nearly all cases I have been able to provide further details, edit and improve these descriptions from my observations on materials examined.

A major exception to the above occurs with the species of *Arthroderma*, *Nannizzia* and *Ajellomyces*, which, with the exception of *Arthroderma curreyi*, were taken, with some reorganization and editing, directly from the published descriptions. Editing in this case involved standardizing terminology (e.g. changing "bone-shaped" and "ossiform" to ossiform throughout). Where UAMH isolates were available, brief examinations of up to 3 strains each (sometimes more) were made. Cultural characteristics for one of these strains (ideally one isolated from the type collection and termed "type strain") were recorded.

Numerical values in the descriptions are mostly ranges obtained by examination of several microscopic fields per collection and measurement of a sample judged to be representative. Measurements were taken with an ocular filar micrometer.

Format of descriptions

Descriptions are presented in order of the following: taxon, author, date, publication and illustrations (if any) provided with the original publication of the name. (Except in headings, date of publication follows the reference.) The format is similar for basionyms. References to illustrations provided in this thesis are underlined. The type (or lectotype or neotype) is then listed under genus entries. Under species entries, "type material" includes the status and nature of the type, place of origin (Country, State or Province) and any other relevant data associated with the packet. The rest of each entry is listed in order of taxonomic importance of various features: ascomata, ascospores, asci, peridial hyphae, appendages, anamorph and culture characteristics on 2 or 3 types of media (including CER, DSA, and PYE). For most Gymnoascaceae,

characteristics on PDA are also provided.

This organization is different from most other treatments, which list these items in almost the opposite order. The rationale behind the arrangement used here is that the worker faced with specimens, either in pure culture or on natural materials, (usually) requires ascomata first to begin an identification. Secondly, and regardless of the nature of the specimen, ascospores are usually the most important source of taxonomic information. From here one works toward the outside of the ascoma, finally looking at cultural characters.

Next is a section entitled "Notes" with comments on one or more of the following: identification or nomenclatural problems with the taxon; habitat; remarks on distribution and/or any other noteworthy aspects specific to the taxon.

"Material examined" gives a list of the specimens studied during preparation of the description. These are listed as briefly as possible, in order of: loaning institution (acronym in bold type), number or other identification marks, source material, location and any other relevant information associated with the packet. Unless otherwise stated, materials examined were derived from desiccated cultures.

Finally, there are no dichotomous keys in this thesis. Since relatively few taxa presented here, and since I agree with Korf (1972) that dichotomous keys are not necessarily the most useful tool for the identification of fungal taxa, I have provided pictorial keys instead, arranged as diagnostic tables for each family and genus. These tables are located in the introduction to each taxonomic part (Tables 1.3, 4.1, 5.1, 5.2, 6.1 and 7.1). When attempting to make an identification the diagnostic tables permit one to see at a glance which taxon his isolate resembles. Comparison with the detailed description and illustrations should be made for confirmation. For an overall taxonomic appreciation of the groups, the tables quickly convey the chief morphological features involved in each division. For most genera the type species is illustrated. For some genera, e.g. *Auxarthron*, illustrations are provided for additional species.

# CHAPTER 3

## TAXONOMY OF THE ONYGENALES

### Status of the order Onygenales in class Ascomycetes

Since the application of Luttrell's developmental concepts to Ascomycete classification (Luttrell, 1951), many traditional ascomycete families and orders based on gross morphology, are in a state of flux (Alexopoulos and Mims, 1979; Barr, 1983; Benny and Kimbrough, 1980; Malloch, 1981b). Because of this, the place of the order Onygenales in the Ascomycetes merits some discussion.

The subclass Plectomycetidae has been defined by Alexopoulos and Mims to include ascomycetes producing single-celled ascospores in thin-walled evanescent asci that are irregularly disposed (i.e. not forming an hymenium) within a peridium differentiated in the form of a cleistoperidium, or within thin wefts of hyphae which form an arachnoid covering. The families and genera included this subclass are listed in Table 3.1 on the following page.

The Plectomycetidae is an artificial group, but I am unable at this time to reconcile my own observations with modern theories such as found in Barr (1983) and Malloch (1981b) which suggest more "natural" organizations. Gaumann (1952) recognized 5 families within the order Plectascales and Dennis (1981) placed 8 families in the same order. Alexopoulos and Mims *op. cit.* recognized 5 orders in the subclass Plectomycetidae: Ascosphaerales, Elaphomycetales, Eurotiales, Microascales, and Onygenales. This system agrees with that used by Benny and Kimbrough (1980) in their synopsis of the Plectomycetes with the exception that the latter authors split the Microascales into two orders, Monascales and Ophiostomatales.

Malloch (1979, 1981b) proposed a radically different system which reflected a much broader concept of component orders. He considered the assemblage usually treated as plectomycetes to be distributed between four major orders: Pleosporales, Hypocreales (including many Eurotiales in the Trichocomataceae), Diaporthales (including Microascales) and Pezizales (including the Monascales and Onygenales as families). His proposal for including Onygenaceae (incl. Gymnoascaceae) in the Pezizales was not supported by Benny and Kimbrough

TABLE 3.1

FAMILIES OF THE PLECTOMYCETIDAE (Alexopoulos and Mims 1979)

CLASS ASCOMYCETES

SUBCLASS PLECTOMYCETIDAE

ORDER ASCOSPHAERALES

Family Ascosphaeraceae

ORDER ELAPHOMYCETALES

Family Elaphomycetaceae

ORDER MICROASCALES

Family Microascaceae

ORDER EUROTIALES

Family Monascaceae
Family Amorphothecaceae
Family Cephalothecaceae
Family Eurotiaceae

ORDER ONYGENALES

Family Gymnoascaceae
Family Onygenaceae

*op. cit.* who noted that pezizalean anamorphs are blastoconidial; cleistocarpous forms have persistent asci with an identifiable operculum; ascospore shape and ornamentation are different; and the sexual apparatus of established members of the Pezizales is very different.

Both Benny and Kimbrough, and Alexopoulos and Mims recognized the Onygenales as a distinct order within the plectomycetes and as is done here, Alexopoulos and Mims included only traditional Gymnoascaceae and Onygenaceae. Benny and Kimbrough also included the Dendrosphaeraceae apparently on the basis of arthroconidium production in the type species of the genus *Dendrosphaera*. Kobayasi (1976) figured conidiogenous hyphae which resemble phialides and his description mentions that the anamorph has an apical penicillus of metulae. These points would indicate that the anamorph of this species is probably not arthroconidial and therefore inclusion of this tropical genus in the Onygenales cannot be supported here. Furthermore, *Dendrosphaera* produces rhizomorphs in the soil upon which it fruits; a characteristic not shared by other fungi in the Onygenales. It has much larger ascospores, (17*u*m diam.), which are sheathed. Other than its stipitate habit it has little in common with *Onygena*. Since no specimen of *Dendrosphaera* was examined during this study suggestions for an alternative taxonomic disposition must await further investigations.

**A comparison of the Onygenales with other orders of the Plectomycetidae**

Onygenales and Ascosphaerales

Ascosphaerales (Ascosphaeraceae, *Ascosphaera*) differs from other plectomycete groups in so many respects that Barr (1983) placed the order in its own class, "Ascosphaeromycetes." Most important of these differences is that ascospores are produced in a spore cyst derived from a single cell ("nutriocyte"), i.e., there is no peridium derived from hyphae (Skou, 1982). In addition, the order differs from Onygenales in possessing a sexual apparatus with a trichogyne. It is interesting that this animal parasite has a thallic anamorph similar to the Onygenales.

Onygenales and Elaphomycetales

Alexopoulos and Mims suggest large size (0.5-5cm diam.) and subterranean habit are the main characters distinguishing this order from the Onygenales. In most treatments, the Elaphomycetaceae is considered distinct from the Onygenales. An exception occurs with *Diehliomyces*, an ascomycete with a loose, non-membranous arrangement of peridial hyphae. It is also reported to be arthroconidial (Gilkey, 1954). However, because of the system of *venae internae* (spore-bearing folds) of the centrum and the unique, smooth, spherical, thick-walled, hyaline spores containing a prominent oil droplet (PL 5.1b), *Diehliomyces* is excluded here as a member of the Onygenales. During my own examination of this species (PREM 33387), I did not find arthroconidia. Barr (1983) considered the Onygenales distant from the Elaphomycetales and placed the latter group in the Parenchymatomycetidae.

Onygenales and Microascales

Members of the Onygenales are easily distinguished from the Microascales, which have darkly pigmented ascospores, one or more germ pores and annellidic anamorphs.

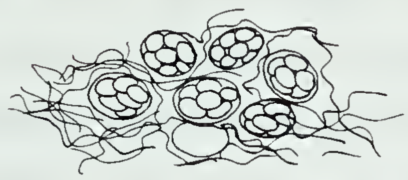
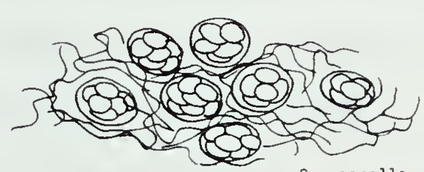
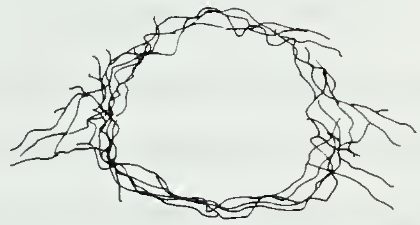
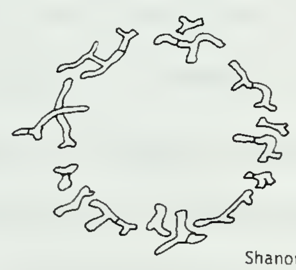
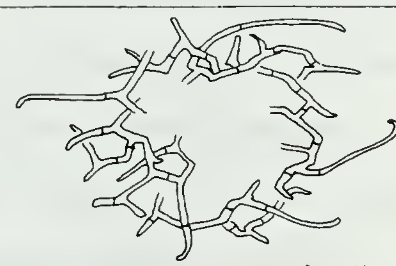
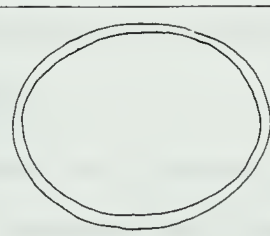
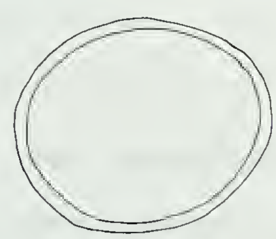
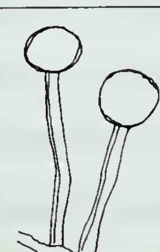
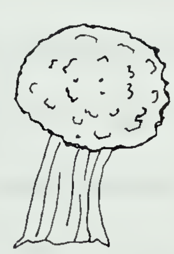
Onygenales and Eurotiales

Fennell (1973) included the Gymnoascaceae and Onygenaceae in the Eurotiales. The strongest distinction between these similar groups is in the mode of conidiogenesis. All members of the Eurotiales have phialidic anamorphs (where connexions have been made). Alexopoulos and Mims refer to the anamorph of *Monascus* (Monascaceae, Eurotiales) as "arthrosporous," However, the anamorph *Basipetospora rubra* has been well described by Cole and Kendrick (1969) and Cole and Samson (1979), as an example of retrogressive conidiogenesis. The mature conidia dehisce schizolytically rather than rhexolytically. The families of the Eurotiales are discussed below since their ascomata exhibit a series of morphological types similar to those in the Onygenales (see Table 3.2).

*Amorphotheca*, the type and only member of the Amorphothecaceae was first proposed as a member of the Gymnoascaceae (Parberry, 1969). Alexopoulos and Mims suggest that the amorphous, melanoid, membranous peridium of *Amorphotheca* prevents its inclusion in the Gymnoascaceae. More importantly, the

TABLE 3.2

**COMPARISON OF FRUITING BODIES IN THE EUROTIALES AND THE ONYGENALES**

| | Eurotiales | Onygenales |
|---|---|---|
| Naked asci |  Byssochlamys |  Gymnascella |
| Telaperidium |  Talaromyces |  Amauroascus |
| Incomposito-peridium | ? |  Shanorella |
| Reticuloperidium | ? |  Auxarthron |
| Cleistoperidium |  Eurotium |  Aphanoascus |
| Stipitate stroma |  Penicilliopsis |  Onygena |

anamorph, *Hormoconis resinae* has darkly pigmented, schizolytically dehiscing blastoconidia in chains.

The monogeneric Cephalothecaceae has phialospores, brown ascospores, and a unique peridial structure not found in other groups.

The Eurotiaceae (Trichocomataceae *fide* Malloch), includes a number of species with teleomorphs that can be easily mistaken for some genera in the Onygenales. In fact, during my herbarium studies, I found that many species in this group were frequently misidentified as "*Gymnoascus* sp." Kuehn (1958), following Benjamin (1956), included *Byssochlamys*, an organism which produces a scanty peridium of scarcely differentiated hyphae in his treatment of the Gymnoascaceae. *Byssochlamys* has a distinctive *Paecilomyces* anamorph. *Hamigera* Stolk and Samson is a similar genus but has a *Penicillium* anamorph. *Sartorya* produces distinctive *Aspergillus* anamorphs and forms asci within several layers of loosely interwoven hyphae - a traditional trait of the "Gymnoascaceae." This type of peridium is again encountered in *Talaromyces* which has *Penicillium* anamorphs. Ascospores of *Talaromyces* are distinctly spiny, a feature absent in the Onygenales. Ascospores in many Eurotiaceae typically have a "pulley-wheel" shape and although equatorial ridges may be absent in some taxa, these modifications are usually pronounced and may be quite ornate. Both *Gymnascella confluens* and *Arachniotus ruber* (both treated here in the Gymnoascaceae) produce ascospores with equatorial depressions, and, although they have not been observed to produce phialidic conidia, the ascospore shape may be evidence that the Gymnoascaceae is a heterogeneous group.

Onygenales and Endomycetales

Relationships between these two groups generally have been considered remote. An exception was Redhead and Malloch's (1977) rearrangement of the Endomycetaceae which included arthrosporic *Galactomyces* (incl. *Endomyces*) in the Onygenaceae. Supporting this proposal was a presumed relationship due to the association of *Galactomyces* with "animal products" (milk), and ascospores with equatorial grooves. Although *Galactomyces* does have arthroconidia, they are schizolytic and not rhexolytic in their dehiscence. They are also produced with quantities of slime which is in contrast to the dry conidia of all other

Onygenalean anamorphs. Further, this genus is not associated with keratinous substrates; ascogenous hyphae do not develop from coiled initials; ascospores develop in groups of less than 8 and have equatorial grooves which are rare in the Onygenales (being present only in a few of the Gymnoascaceae which have questionable affinities).

**Morphological characters in the Onygenales and their taxonomic usefulness**

Gametangia

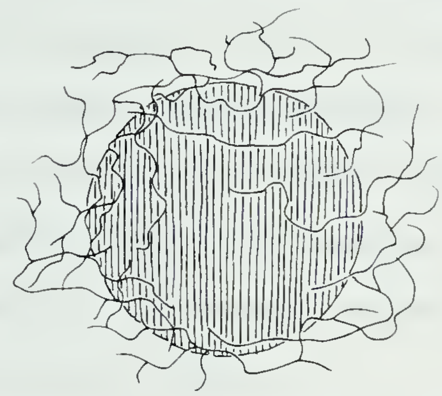
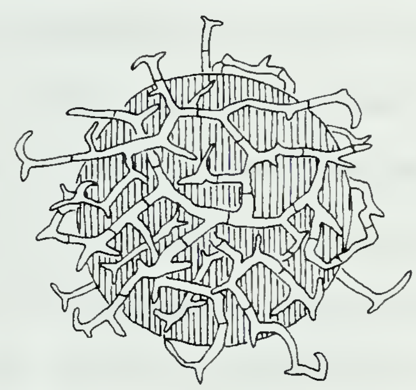
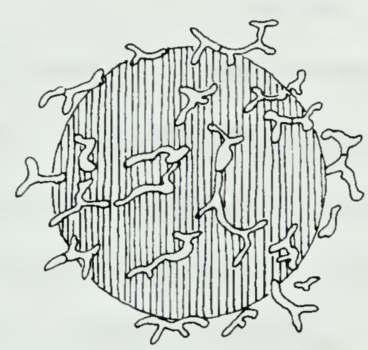
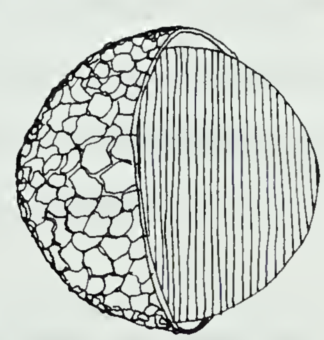
The members of the Onygenales demonstrate a diverse range of ascomatal types and although their morphology at maturity is well documented, developmental studies in the group are few (Dale, 1903; Dangeard, 1907; Kuehn, 1956; Kwon-Chung, 1973). It is therefore with some difficulty that generalizations are made concerning developmental aspects. Figure 3.1 illustrates some stages and structures involved in gametangial pairing.

Fertile ascomata are initiated by the formation of paired gametangial hyphae which arise from either the same or different hyphae of one strain in homothallic forms. In heterothallic species the initials in each pair arise from strains of opposite mating type. Detailed studies on mating behaviour and compatibility systems for members of the Onygenales are few and concentrate mainly on the medically important species in the Arthrodermataceae (Aschan-Aberg and Thyresson, 1967; Kwon-Chung, 1972; Maniotis and Chu-Cheung, 1973; Padhye and Carmichael, 1969, 1971, 1973; Sekhon and Padhye, 1976; and Stockdale, 1968; and *Ajellomyces* (Kwon-Chung, 1971, 1973) (Onygenaceae). In some instances the formation of apparently normal ascomata can occur without prior formation of normal initials. These structures on closer inspection are sterile and lack ascospores but may sometimes be filled with conidia. The sterile structures have been called "pseudothecia" and occur in all families of the order except the Gymnoascaceae (see Sigler and Carmichael, 1976). Pseudothecium also refers to ascostromatic ascocarps having asci in numerous unwalled locules (Bitunicatae) and therefore the use of this term should be discouraged in the Onygenales. The structures filled with conidia are not usually called pycnidia although a case could be made for so doing.

Events following gametangial pairing are not strictly consistent within families,

TABLE 3.3

**PERIDIAL TYPES IN THE ONYGENALES**

| | |
|---|---|
| Telaperidium |  |
| Reticuloperidium |  |
| Incompositoperidium |  |
| Cleistoperidium |  |

genera or even species and exhibit a great deal of variation from one author to another (Kuehn, 1956).

Contact between gametangial branches may be either very simple as in *Uncinocarpus reesii* and *Amauroascus mutatus* (Onygenacaeae) where adjacent tips form only "knobs" (Sigler and Carmichael, 1976; Dangeard, 1907 as *Amauroascus verrucosus*); or very elaborate, as in *Gymnoascus reessii* (Gymnoascaceae), where paired gametangia first mutually coil about one another two to three times. One branch then differentiates to become an "ascogenous" branch (archegonial coil) and winds about the club-shaped partner (antheridium). Gametangial contact of an intermediate nature has been observed in *Myxotrichum deflexum* (Myxotrichaceae) (Kuehn, 1956), *Uncinocarpus uncinatus* (Onygenaceae), *Nannizzia incurvata* (Stockdale, 1961), *Arthroderma curreyi* (Udagawa and Furuya, 1977) and *Aphanoascus fulvescens* (Dangeard, 1907). In these taxa, one initial (antheridium) remains relatively straight and clavate while the other (archegonial branch) coils several times about the antheridial axis. Fennell (1973) states that the antheridium of the Gymnoascaceae is often "non-functional." This refers to the apparent lack of exchange of nuclear material. There is apparently no dissolution of the walls between the gametangia except in very few genera (e.g. *Ajellomyces* McDonough and Lewis, 1968). Asci arise with or without crozier formation and following distal enlargement of both branches and septation of the archegonial coil. These events and/or structures may present valuable taxonomic information at the genus level (Von Arx, 1971, 1974, 1977) but the data are not yet complete enough to make conclusive statements. Much more experimental work is required to assess variability in this phase since Von Arx has limited his observations to very few strains. Such characters have proved useful in other cleistothecial groups, especially the Eurotiales (Benjamin, 1955; Stolk and Samson, 1971, 1972). Certainly some taxa have distinctive gametangia and I have used such data to support removing one questionable genus from the order (*Arachnomyces*) (see Chapter 8, Excluded Genera).

<u>Peridia and appendages</u>

The peridium in this group has received a great deal of attention since this structure, more than any other, has been used to characterize typical

gymnoascaceous fungi. Reduction of the peridium and homologous structures has occurred in several major groups of ascomycetes including Eurotiales (e.g. *Byssochlamys* and *Hamigera*) and Pezizales (e.g. *Ascodesmis*, *Eleutherascus*). Mesh- or bramble-like peridia also occur in the Eurotiales (*Talaromyces* and allies) (Stolk and Samson, 1972) and *Elaphomyces* (Elaphomycetales). Clearly, membranous peridia are widespread in many different groups of fungi.

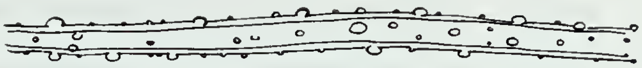
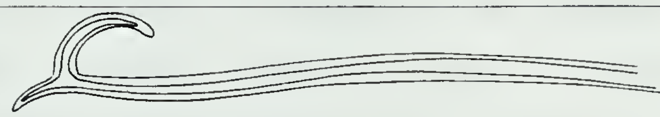
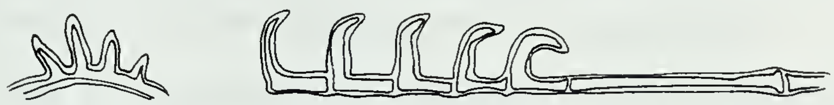
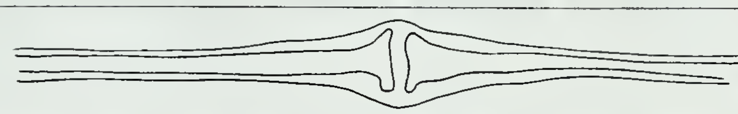
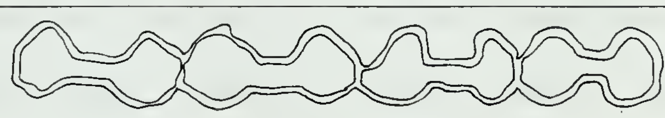
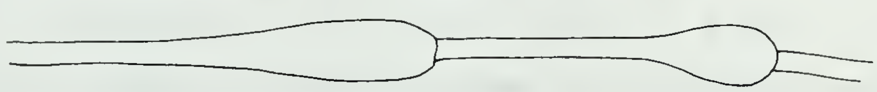
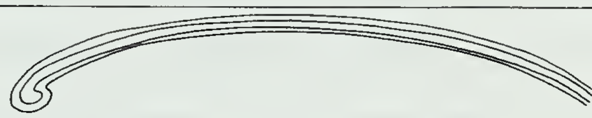
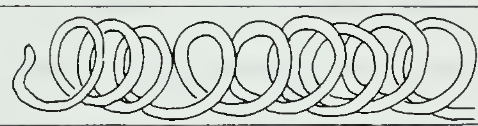
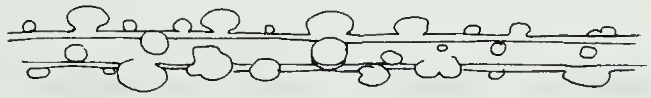
In the Onygenales, as in other orders of ascomycetes, peridial characteristics are useful at the genus and species levels. Exclusive reliance on peridial characters can be misleading, since they have been shown to be not only highly variable but also quite similar in otherwise very different genera (cf. *Gymnoascus*, *Auxarthron*, and *Uncinocarpus*).

Peridial hyphae (when present) arise from either the base of the antheridial initial and/or from surrounding vegetative hyphae in the immediate proximity to the coil(s). It is not uncommon to observe a number of paired initials within the developing peridium of one ascoma. In *Gymnoascus intermedius* (Gymnoascaceae) and *Myxotrichum bicolor* (Myxotrichaceae), peridial hyphae do not regularly form discrete aggregations, and instead form extensive mat-like ascomata with localized conglomerations of ascospores.

The peridium in many Onygenales is a bramble-like assemblage of more or less differentiated hyphae. There are no reports on the exact organization of these hyphae since, unlike many other groups of ascomycetes, studies using serially sectioned material have not been documented. It is virtually impossible to determine structural features in squash preparations. I have recognized 4 types of peridia in the Onygenales: reticuloperidium, incompositoperidium, telaperidium, and membranous peridium. In general, non-membranous peridia are referred to as "hyphal peridia." Table 3.3 provides diagrammatic illustrations of these peridial types. In general, reticulothecial forms produce a mesh-like peridium of richly branched and more or less anastomosed, thick-walled hyphae which presumably allow ascospores to sift out through the inter-hyphal spaces. Probably these forms are adapted to active dispersal by animals, including insects, birds and mammals. Most reticuloperidial forms have appendages such as hooks, crooks, coils, spines, or even comb-like structures (*Ctenomyces*) which would serve to

TABLE 3.4

DIAGRAMS OF SOME TERMS APPLIED TO THE PERIDIAL CELLS AND APPENDAGES OF THE ONYGENALES

| Adjective / Term | Diagram |
|---|---|
| Acute |  |
| Asperulate |  |
| Bifurcate |  |
| Boat hook |  |
| Constricted at septum |  |
| Ctenoid |  |
| Deflexed |  |
| Knuckle joint |  |
| Ossiform |  |
| Racquet hypha |  |
| Scimitar |  |
| Helix |  |
| Tapered |  |
| Tuberculate |  |
| Uncinate |  |

latch on to bristles, hairs, feathers etc. (Plate 4.1b).

In most reticuloperidial Onygenales, distinctive appendages are produced. These may be individual thick-walled hyphae, helices, or in some Arthrodermataceae, macroconidia. In some species there is some question as to where to differentiate between appendages and peridial hyphae. Appendage refers here to any non-sexual structure extending beyond the perimeter of the ascoma that is obviously different from typical vegetative and/or peridial hyphae. Appendages and some types of hyphae associated with ascospore production in the Onygenales are illustrated in Table 3.4.

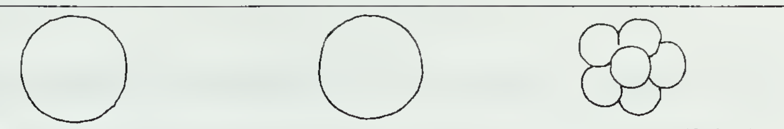
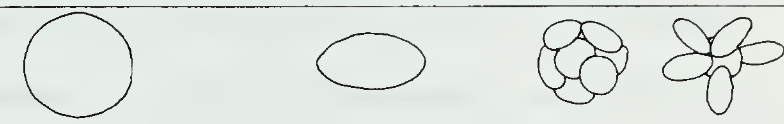
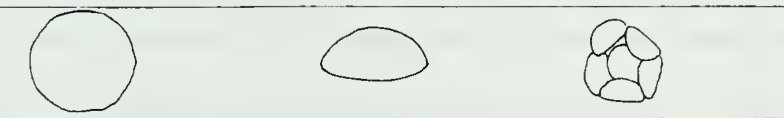
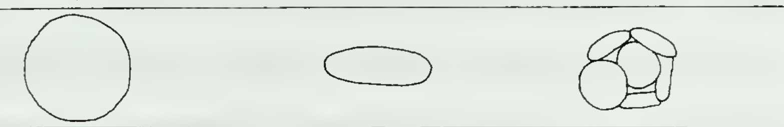
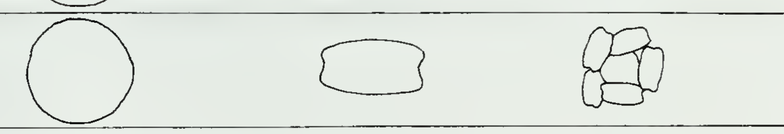
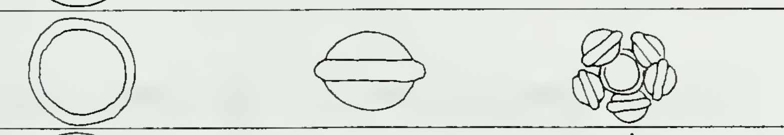
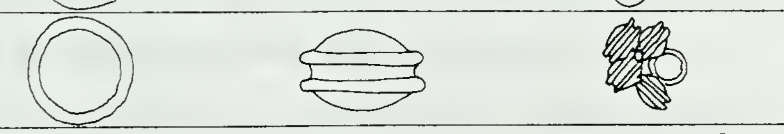
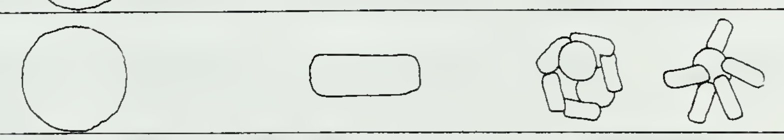
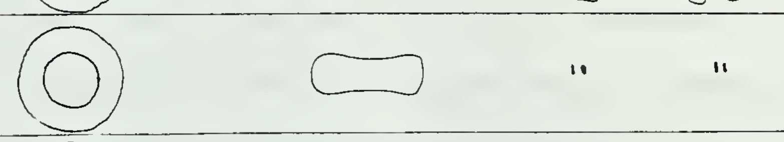
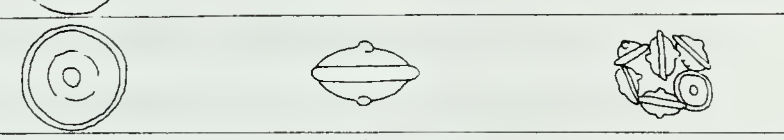
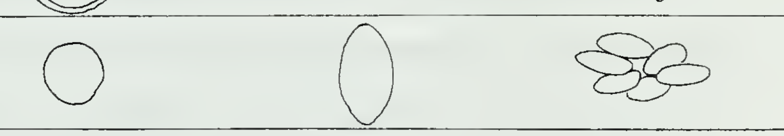
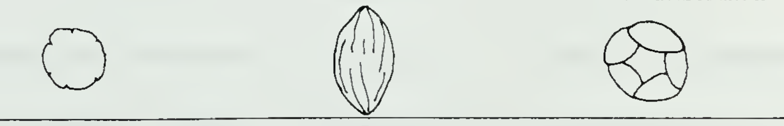
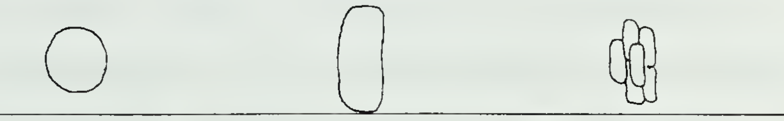
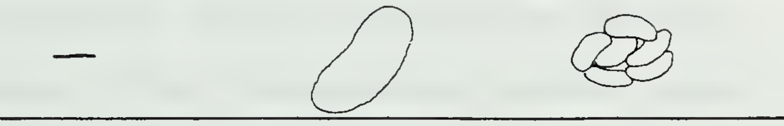
In some forms, the peridium at maturity is reduced to an apparently unorganized mass of thick-walled, contorted cells. This type of peridium is referred to here as an incompositoperidium and occurs in *Shanorella* (Onygenaceae) and in some species of *Gymnascella* (Gymnoascaceae). It may represent a transitional form between the reticuloperidium and telaperidium.

The telaperidium is an envelope of thin-walled hyphae that lack any obvious differentiation from the vegetative hyphae. They form cobweb-like covering over the ascospores. *Byssoascus* (Myxotrichaceae) lacks a peridium typical of other genera in the family. Darkly pigmented hyphae do occur in culture (Sigler and Carmichael, 1976) although these lack any sign of peridial organization. The ascospores are effectively borne amidst apparently undifferentiated vegetative hyphae. In the Onygenaceae, the peridium of *Uncinocarpus reesii* is almost entirely absent, except for the formation of distinct hyphae, which more closely resemble appendages than peridial hyphae. A similar situation exists in *Ajellomyces* which produces striking long coils from the centre of the ascoma. In this genus peridial hyphae arise as lateral outgrowths of these coils. Within the Gymnoascaceae, most species in *Gymnascella* lack recognizably differentiated peridial hyphae although some variations may occur depending on strain, age and environmental conditions.

Cleistoperidia are membranous peridia that occur in what I consider primitive forms. This type of construction is found in the Arthrodermataceae (*Ctenomyces*) and in the Onygenaceae (*Aphanoascus, Keratinophyton* and *Xynophila*). The latter genus also possesses a tomentum of closely packed, apparently undifferentiated

TABLE 3.5

ASCOSPORE AND ASCUS SHAPES IN THE ONYGENALES

| Shape | Polar view | Equatorial view | Ascus shape |
|---|---|---|---|
| spherical |  | | |
| oblate |  | | |
| oblate - convex |  | | |
| oblate - discoid |  | | |
| oblate with broad equatorial groove |  | | |
| oblate with 1 equatorial thickening |  | | |
| oblate with 2 equatorial thickenings |  | | |
| oblate with poles flattened |  | | |
| oblate with polar depressions |  | | |
| oblate with polar and equatorial thickenings |  | | |
| fusiform |  | | |
| fusiform striate |  | | |
| cylindrical |  | | |
| allantoid |  | | |

vegetative hyphae which may enclose one or many ascomata. *Ctenomyces serratus*, when mature, has a membranous peridium immediately surrounding the asci and ascospores. This structure is further enclosed in a thick-walled, mesh-like arrangement of cuticularized hyphae some of which terminate in typical "ctenoid" appendages. This outer structure could be referred to as a reticuloperidium.

Surface characteristics of mature peridial hyphae may be quite striking, but are useful for discrimination mostly at the species level. Warts, puncta and even pedicellate structures are common in most Onygenaceae (*Auxarthron* and *Pectinotrichum* being exemplary in this respect). The peridial hyphae of members of the Gymnoascaceae with rigid reticuloperidia may also be ornamented, while all of the Myxotrichaceae have very smooth peridial hyphae. Members of the Arthrodermataceae are almost always ornamented with blunt knobs or protrusions and appear asperulate or tuberculate.

<u>Ascomata</u>

Most ascomata are visible with the naked eye and are frequently greater in diameter than 100*u*m. Some fruiting structures may be very large. The compound fructifications of *Xynophila* may form cushion-like masses 5-6mm in diameter. *Shanorella spirotricha* forms ascomata enmeshed by hyaline vegetative hyphae and these conglomerations have been measured at 3cm in diameter on natural substrata. Such gregarious formations were never observed in culture. *Auxarthron* species nearly always form single ascomata as do most of the Onygenaceae. In the Myxotrichaceae, ascomata are always single except in *Myxotrichum bicolor*. Ascomata in the Arthrodermataceae also occur singly.

Mature peridial hyphae, whether thin-walled, thick-walled or membranous, usually impart to ascomata a distinctive coloration. White to off-white ascomata are comprised of hyaline peridial hyphae. Yellow and pale brown pigments create various shades of cream, yellow buff or tan. These colors are common in the Arthrodermataceae and Onygenaceae. Although pigments are generally intracellular, some species, particularly in the Gymnoascaceae, produce large quantities of crystalline extracellular pigments which adhere to the peridial hyphae. Bright orange and red pigments, which are mostly crystalline, give

*Arachniotus ruber* and *Gymnascella confluens* their characteristic coloration. In fact, most members of the Gymnoascaceae are brightly colored with shades or orange, red and yellow predominating. Green pigments are elaborated in some strains of *Gymnoascus reessii* and in all strains of *Gymnascella hyalinospora*. Reddish brown pigments occur in the peridial hyhpae of all of the Myxotrichaceae and in some members of the Onygenacaceae which have membranous peridia (e.g. *Aphanoascus, Keratinophyton*). At the macroscopic level these peridia appear black.

Asci and ascospores

In most Onygenales, the ascus membrane is short-lived and disappears by the time the ascospores are mature. Ascospores are conglobate (remain in typical 8-spored clusters) after membrane dissolution. They separate into individual spores when disturbed. Shape of the ascus is of limited usefulness since nearly all representatives have globose or ovoid asci. Several taxa have ascospores that form arrangements similar to the petals of a simple radiate flower. These petaloid arrangements are a consistent feature in the taxa in which they occur. Distinguishing between oblate and spherical spores can be done by observing their disposition in ascal clusters: spherical spores make a polygonal arrangement; oblate spores arrange themselves in tight, more or less spherical clusters.

Ascospores are extremely important sources of taxonomic information, since morphological variations within taxa are slight in comparison with variations between taxa. Ascospore morphology seems not much affected by environmental factors. Size, shape, color and surface ornamentation are all useful characters in delimiting taxa. Table 3.5 illustrates variations in shape of Onygenalean ascospores and asci. Table 3.6 illustrates surface sculpturing found in the order. Due to their small size (none larger than 8*um*), ascospores of the Onygenales must be observed with an oil immersion objective to detect all pertinent characters.

In all members of the Onygenaceae, ascospores are punctate. These puncta range from very minute in *Shanorella spirotricha* to very large in *Auxarthron californiense*. In the latter case ascospores appear reticulate and somewhat

TABLE 3.6

TYPES OF ASCOSPORE ORNAMENTATION IN THE ONYGENALES

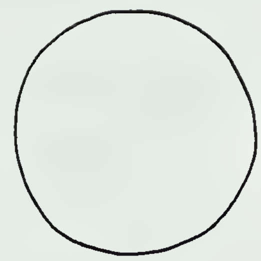
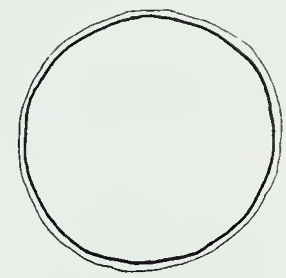
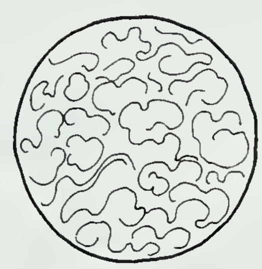
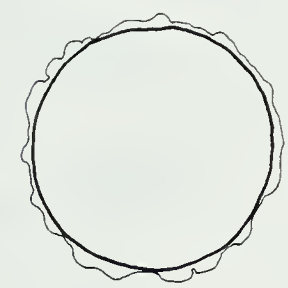
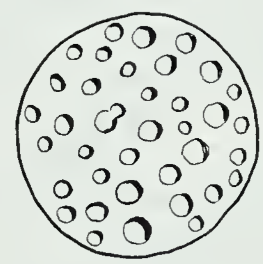
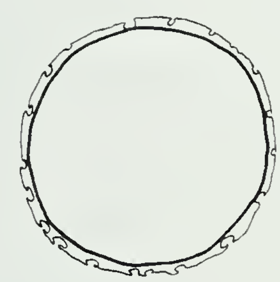
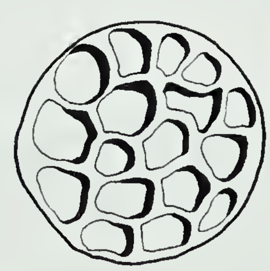
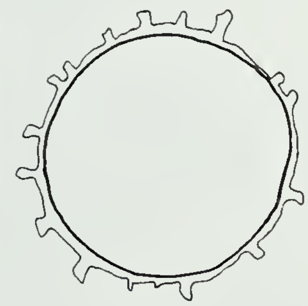
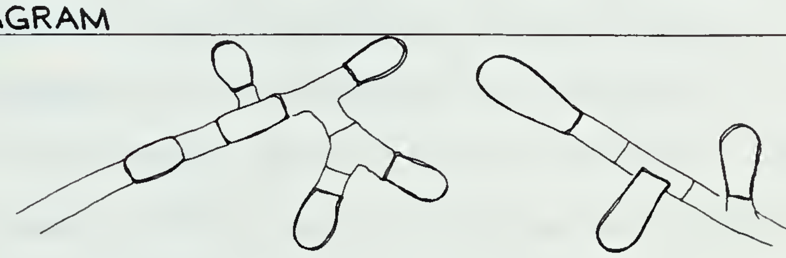
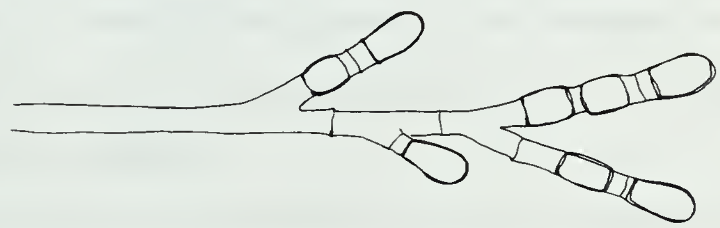
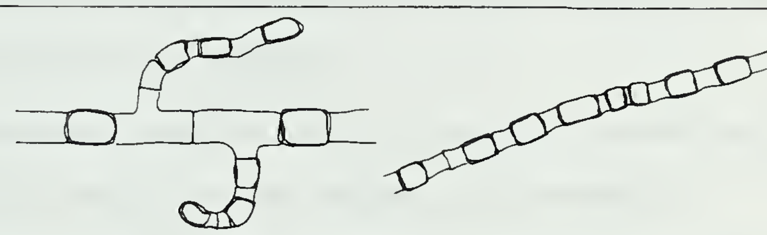
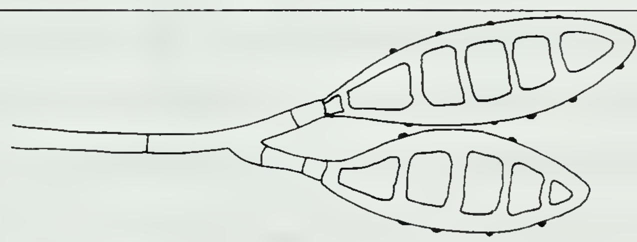
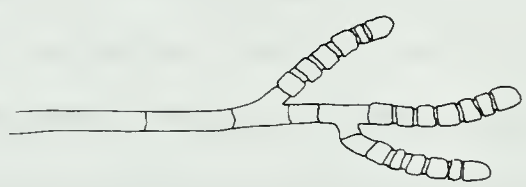
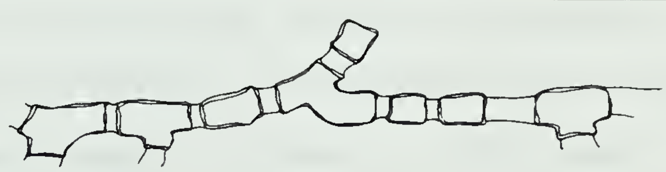
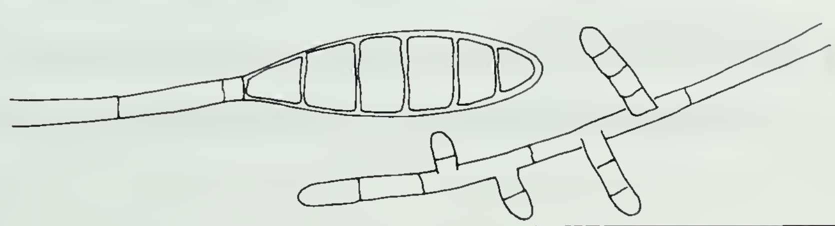
| | Surface view | Sectional view |
|---|---|---|
| Smooth |  |  |
| Undulate |  |  |
| Punctate |  |  |
| Punctate – reticulate |  |  |

TABLE 3.7

DIAGRAMS OF FORM-GENERA IN THE ONYGENALES

| FORM-GENUS | DIAGRAM |
|---|---|
| Chrysosporium |  |
| Geomyces |  |
| Malbranchea |  |
| Microsporum |  |
| Oidiodendron |  |
| Sporendonema |  |
| Trichophyton |  |

spiny due to the side views of punctum walls on the perimeter of the spore. Ascospores in this family are never truly spiny although this adjective occurs in virtually all previous treatments of these fungi. *Talaromyces* (Eurotiales) has true spines as does *Aphanoascus cinnabarinus sensu* Udagawa and Takada (1973) (probably Eurotiales). In cases where puncta are very small, it is necessary to slowly focus up and down using bright field microscopy. Phase contrast obscures minute puncta and is generally not recommended for observing ascospores. Spore shape in the Onygenaceae may be allantoid (*Onygena*), oblate (*Uncinocarpus*), bean-shaped or reniform (*Renispora*), or spherical (*Amauroascus*) and in general, shape is useful in distinguishing genera in the absence of contradictory characters. *Auxarthron* exhibits some variation between oblate and spherical ascospores depending on species.

Most of the Myxotrichaceae have striate ascospores. These striae may be very fine or quite distinct depending upon species.

All members of the Gymnoascaceae have smooth or undulate spores which are usually oblate, with or without polar and/or equatorial thickenings.

With the exception of *Ctenomyces*, the Arthrodermataceae has very small (usually <3.5$\mu$m), smooth, ascospores which are oblate-discoid in shape. *Ctenomyces* ascospores have one slightly flattened polar surface. Equatorial modifications are observed only in the Onygenaceae and Gymnoascaceae and these are important sources of distinctive characters at the genus and species levels. *Keratinophyton* has a thickened, raised, punctate equatorial band which is equally thickened in *Keratinophyton durum* and asymmetrically thickened in *Keratinophyton terreum*. In the Gymnoascaceae, equatorial modifications are reminiscent of *Eurotium* species (Eurotiales). In *Arachniotus ruber*, an equatorial depression is bordered by parallel ridges to produce a "pulley-wheel" shape. *Gymnascella confluens* also has a wide equatorial depression. *Gymnascella marginospora*, *Gymnascella punctata* and *Gymnascella dankaliensis* all have a single equatorial rim. *Gymnascella dankaliensis* is further ornamented by a distinct boss on either pole.

Anamorphs

Anamorphs of the Onygenales are all thallic in their development and all dehisce rhexolytically. Because of the taxonomic significance attached here to the anamorph, definitions concerning dehiscence are quoted from Hughes (1979): rhexolytic: "conidium secession which involves a fracture of the subtending cell;" schizolytic: "conidia are liberated from the subtending cell by a split through the outer wall...one layer remains on the the base of the conidium and the other on the subtending cell."

Anamorph genera associated with the order include: *Chrysosporium* (Carmichael, 1962; Van Oorschot, 1980); *Geomyces* (Sigler and Carmichael, 1976) *Sporendonema* (Samson and Van der AA, 1973; Sigler and Carmichael, 1976); *Malbranchea* (Sigler and Carmichael, 1976); *Oidiodendron* (Sigler and Carmichael, 1976); *Trichophyton* (Padhye and Carmichael, 1971; Rebell and Taplin, 1970); *Microsporum* (Rebell and Taplin, 1970). All of the named genera except *Sporendonema* have been given detailed taxonomic study during recent years, and the references above are to useful treatments. Table 3.7 illustrates diagrammatically, some of the differences among these anamorph genera. Significant taxonomic characters (size, shape, color and surface ornamentation) vary. In *Trichophyton* (anamorph of *Arthroderma*), and *Microsporum* (anamorph of *Nannizzia*) septation, wall thickness and surface roughening are important characters. In *Geomyces* (anamorph of *Pseudogymnoascus*) the branching pattern of the conidiophore is unique.

With respect to family delimitations, anamorph characters correlate relatively well with teleomorph characters. The Arthrodermataceae is the only family which has species producing multiseptate macroconidia. Although some Onygenaceae will form one-septate conidia, none approach the size and complexity of those found in the Arthrodermataceae. In *Nannizzia* and *Arthroderma*, species separation is extremely difficult without considering anamorph characteristics.

*Geomyces*, *Oidiodendron* and *Malbranchea* states are found in the Myxotrichaceae. When these occur without typical conidiophores they may be unnamed (Sigler and Carmichael, 1976).

The Onygenaceae frequently produces anamorphs either named in, or

TABLE 3.8

LEVELS OF COMPLEXITY IN ASCOCARP CONSTRUCTION IN THE ONYGENALES

| Ascocarp type | Families and Genera | | | |
|---|---|---|---|---|
| | Arthrodermataceae | Gymnoascaceae | Myxotrichaceae | Onygenaceae |
| telathecium | | Arachniotus<br>Gymnascella | Byssoascus | Ajellomyces<br>Amauroascus<br>Kuehniella<br>Renispora |
| incompositothecium | | Gymnascella | | Shanorella<br>Spiromastix |
| reticulothecium | Arthroderma<br>Nannizzia | Acitheca<br>Gymnoascoideus<br>Gymnoascus | Myxotrichum<br>Pseudogymnoascus | Auxarthron<br>Nannizziopsis<br>Neogymnomyces<br>Pectinotrichum<br>Uncinocarpus |
| cleistothecium | Ctenomyces | | | Aphanoascus<br>Keratinophyton |
| stroma | | Gymnoascus | Myxotrichum | Ascocalvatia<br>Onygena<br>Shanorella<br>Xynophila |

assignable to, *Chrysosporium*. Arthroconidia are also common in this group and become particularly well-developed in *Auxarthron* where many anamorphs have been assigned to *Malbranchea*.

**Ecological and evolutionary aspects of the Onygenales**

The following discussion relates structure and ecology to possible routes of evolution of the group. This approach is taken since it is necessary to examine the "selective agencies which are probably to have been operative in the development of a particular feature" (Burnett, 1976). The genera in the families of the Onygenales are arranged in four levels in Table 3.8. The levels represent degrees of morphological complexity of the peridium found in the order. I have based the following discussion on the premise that evolution in the ascomycetes has proceeded toward reduction in complexity of the ascoma (Cain, 1972).

Because there is a lack of information on the fossil record of these (and most other) fungi (Pirozynski, 1976), and generally a lack of living material for study for many taxa, some limitations are placed on providing a worthwhile discussion of the phylogeny of the order. I am also aware that there are numerous, undescribed taxa in this group. Information to be derived from these, as yet undescribed, taxa will have considerable bearing on phylogenetic reconstructions.

Further, there are few pertinent ecological treatments. Published work on coprophilous fungi shows a marked lack of records of Onygenalean fungi (e.g. Angel and Wicklow, 1983a, b). A recent comprehensive monograph (Wicklow, 1981) on fungal ecology limits the discussion of keratinolytic species to a passing mention (in one sentence!).

The relationship of structure to ascospore production and propagule dissemination is founded on a reliance on or association with animals. Various structural modifications of the peridium have arisen in response to this relationship, and some examples are drawn below.

All of the Onygenaceae have hyaline or light-colored ascospores. Hyaline ascospores are susceptible to damage by UV and therefore require protection during development. This can be accomplished in two ways: either by expending energy in production of a protective cover; or by forming meiospores in a

TABLE 3.9

THE PLESIOTYPIC (-) AND APOTYPIC (.5, 1) STATES OF SEVEN CHARACTERS USED IN RECONSTRUCTING A PHYLOGENY FOR THE THREE GENERA OF THE ARTHRODERMATACEAE

| | *Arthroderma* | *Ctenomyces* | *Nannizzia* |
|---|---|---|---|
| A Nature of the peridium (membranous/hyphal) | 1 | .5 | 1 |
| B Ascospore shape (asymmetric/symmetric) | 1 | .5 | 1 |
| C Appendage morphology (thick-walled/thin-walled) | 1 | - | 1 |
| D Spiral hyphae (absent/present) | 1 | - | 1 |
| E Pathogenesis (non-pathogenic/pathogenic) | 1 | - | 1 |
| F Pigmentation (pigmented/nonpigmented | .5 | 1 | .5 |
| G Ossiform cell (end(s) expanded and irregular/ ends only slightly swollen) | - | - | 1 |
| | ABCDEF/2 | A/2B/2F | ABCDEF/2G |

protected microenvironment such as an animal burrow.

*Onygena* is at present the most complex member of the order. Individual ascomata form within a stromatic structure which provides a protected environment for meiospore formation. *Onygena equina* is found almost exclusively on hoof and horn. Ungulates inhabit open areas (grasslands) and after death carcasses remain exposed. The stromatic nature of the head of *Onygena* provides protection for meiospore development in these exposed situations. After maturation of the ascospores the stroma ruptures and ascospores are released. The likelihood of either the ascospores or the arthroconidia successfully wind disseminating to another hoof or horn is extremely low. The biology of *Onygena* remains a mystery, and a satisfying hypothesis on dispersal has not yet been proposed. However, I suggest that *Onygena* is disseminated by insects, probably carrion flies, which, in their search for decaying animal products, would serve to transport the fungus to suitable new habitats. This dispersal mechanism finds a parallel in the bryophyte family Splachnaceae which grows mostly on bones, dung or other decaying materials (Crum, 1976).

In taxa with less differentiated ascomatal structures, the meiospores require another source of protection. Taxa in the genera with reduced peridia are adapted to fruiting underground in animal burrows where substrate is plentiful, humidity is high and constant, and damaging UV is absent. In these situations formation of elaborate peridia (and forcible ejection of ascospores - absent in all Onygenales) is a waste of energy. The major biological problem is dispersal and this ultimately rests with animal inhabitants of the burrow.

The structure of the peridium of such genera as *Gymnoascus* (Gymnoascaceae) and *Auxarthron* seem to be designed either to latch on to various animals (arthropods, rodents) or to be disturbed by any type of movement in the vicinity. While it is well known that many dark-spored ascomycetes with violently ejected ascospores have a physiological requirement for passage through the guts of herbivorous animals for germination, the explanation for dispersal from faeces to faeces for predominantly coprophilous Onygenales has much less experimental evidence that gut passage is a requirement for germination (Brierly, 1917; Tubaki, 1960).

Movement from one habitat to another could be effected in much the same way as hypothesized for *Onygena*, i.e. transmission from site to site by insects. Alternatively, colonization of new sites could be effected by gut passage in which case ingestion would probably occur through grooming habits or by ingesting other animals which have come in contact with sporulating colonies.

The significance of the thallic mode of conidiogenesis has not yet become apparent. It may have special significance to dispersal mechanisms. The Ascosphaerales, which cause diseases of honey bees, produce arthroconidia similar to those of the Onygenales. Thallic anamorphs are also found in many families of the order Agaricales (Watling, 1979). Watling felt that they may act in the Agaricales as spermatia and may also improve competitive ability through suppression of the growth of other fungi in a given microhabitat. Whether or not these characteristics are specific to this mode of conidiogenesis is unknown.

Cellulolytic Onygenales (Myxotrichaceae) also have reticuloperidia which superficially resemble those in other families of the Onygenales. Conidia are also thallic. *Pseudogymnoascus*, primarily a soil-borne fungus, is occasionally isolated from rhizospheres of higher plants. It has never been implicated as a pathogen and presumably breaks down the cellulosic fraction of sloughed root cells. The reticuloperidium and ascospores are pale rose in color and this probably indicates a reliance on burrowing animals for dispersal. *Elaphomyces* (Elaphomycetales) which also has a hyphal peridium and a subterranean habit, no doubt has similar dispersal mechanism.

The species of *Myxotrichum* fruit on paper, straw and other cellulosic materials. One taxon fruits on lichens. The dense reticuloperidium is black to the naked eye and this intensity of pigmentation is probably an adaptation to fruiting in exposed situations. The elaborate appendages in this genus appear to be attachment structures to facilitate dispersal by animals.

There are some interesting parallels between the parasitic Onygenales and other parasitic fungi. The two keratinolytic families have each developed several pathogenic representatives. In the Arthrodermataceae, many species of *Nannizzia* and *Arthroderma* cause ringworm diseases of man and other animals. In the

Onygenaceae, *Ajellomyces* causes deep mycoses in man. Loss or reduction of structures accessory to meiospore production has also occurred in other parasitic ascomycetes (Taphrinales) and in plant parasitic basidiomycetes (Uredinales, Ustilaginales and Exobasidiales). The basidiomycetous animal pathogen *Cryptococcus neoformans* (*Filobasidiella*) also has an extremely reduced teleomorph.

The Onygenales, although exhibiting some consistent morphological characters, is undoubtedly polyphyletic. I am relatively certain that the families Onygenaceae, Myxotrichaceae and Arthrodermataceae are, internally at least, monophyletic, and I feel also that a case may be made for stating that the Arthrodermataceae and Onygenaceae have had a recent common origin. As stated previously, I have reservations about the disposition and relationships of the members of the Gymnoascaceae.

Figure 3.2 is a phenogram constructed as a flow chart to illustrate some key characters in the keratinolytic Onygenales. It may represent, to some extent, phylogenetic relationships, but these would be difficult to argue at this point. Concerning the construction of phylogenetic trees, Cain (1972) illustrated the major problem with the fungi.

> " Most features found in the Ascomycota and to some extent in the basidiomycota [sic] (excluding such complex features as the spore discharge mechanisms) have appeared separately in two or more lines. It is relatively easy to find characters which appear to be connecting links between various taxa at almost any level including genera, families and orders. Unfortunately, when all these connections are put together you find that any particular taxon can be linked in all directions rather than in an orderly ascending phylogenetic tree. An almost infinite number of such trees can be constructed depending on the features chosen at any particular level. "

Phylogenetic theories in mycology are rather rare when considered against the quantity of this type of work with animals and green plants (Wiley, 1981; Funk and Brooks, 1981). Alexopoulos and Mims give only a small list of very general references to phylogenetic work in the fungi.

Nevertheless, I have applied Wagner's ground plan divergence method (Wagner, 1980) for reconstructing the phylogeny of the Arthrodermataceae. Distribution of plesiomorphic and apomorphic states are found in Table 3.9.

Seven characters were selected for the construction of the Wagner tree

Figure 3.1. Gametangia in the Onygenales.

**a** A pair of gametangial hyphae ('gh') arising from a common hypha. (Figures a, b, c, d, and e are a sequential series of copulatory events).

**b** Contact between gametangial hyphae.

**c** Paired gametangial hyphae mutually coiling about one another.

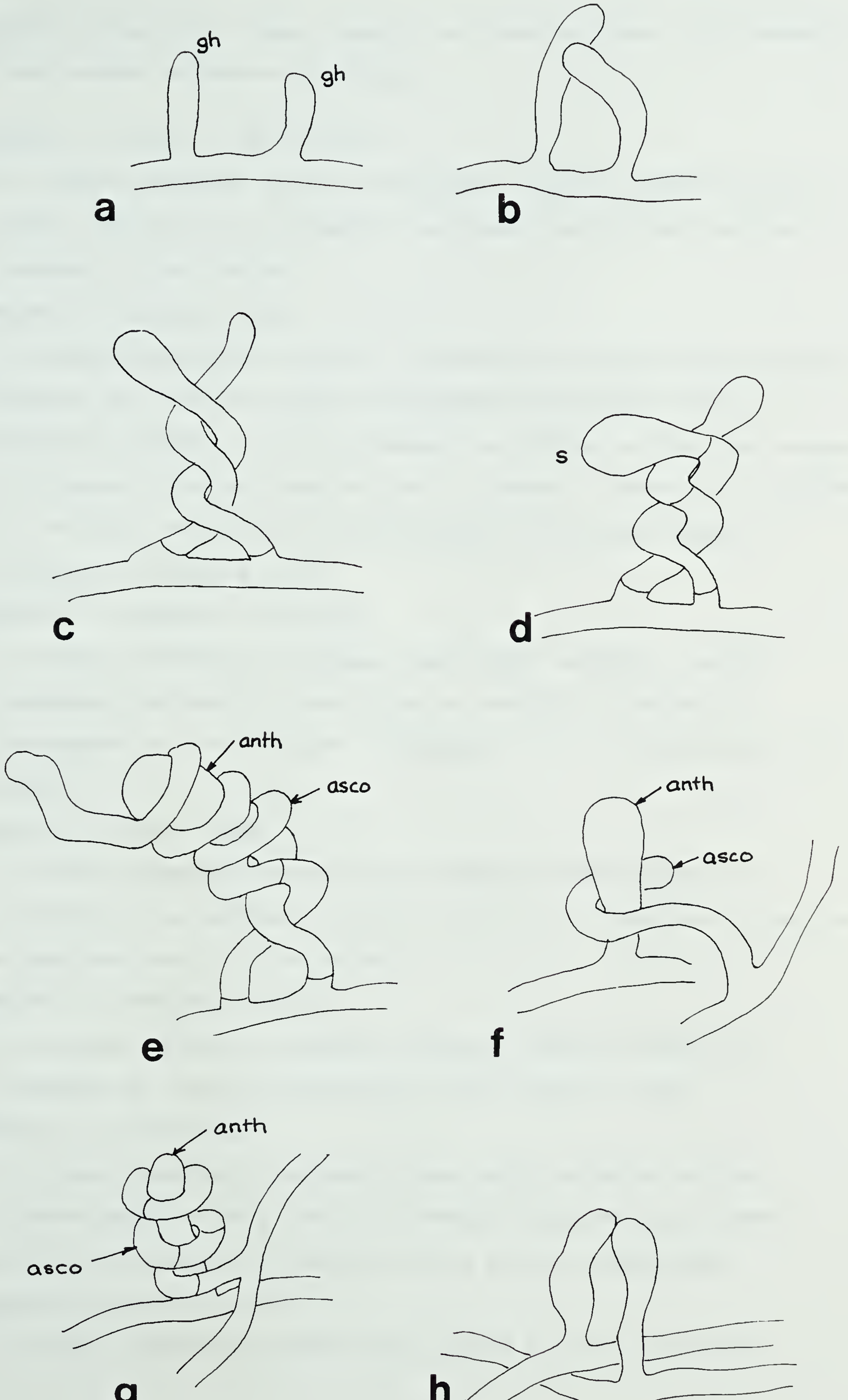
**d** One gametangial hypha ('s') becomes swollen at the tip; both become septate.

**e** Central, swollen, club-shaped branch is antheridium ('anth'); finer encircling hypha is the ascogenous branch or archegonial coil ('asco'). This pairing is typical of *Gymnoascus reessii*.

**f** A pair of gametangial hyphae arising from different parent hyphae. Central cell is the antheridium ('anth'). Coiling branch is the ascogenous coil ('asco'). No mutual coiling occurs. (Figures f and g are a series).

**g** Coiling archegonium with central club-shaped cell. This type of pairing is typical of *Nannizzia incurvata*.

**h** Simple pairing of knob-like initials as found in *Amauroascus mutatus* and *Uncinocarpus reesii*.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illustrated in Figure 3.3. These characters are presented below with reference to their possible evolutionary significance.

Character A. *Nature of the peridium.*

Two states: plesiotypic, peridium membranous; apotypic, peridium hyphal. In general, the trend in the Onygenales has been toward greater reduction in complexity of the peridium.

Character B. *Ascospore shape.*

Two states: plesiotypic, single axis of symmetry (ascospores oblate convex); apotypic, two axes of symmetry (ascospores oblate-discoid). Based on character correlation in the Onygenaceae. The primitive stromatic and stipitate fruit bodies of *Onygena* have no lines of symmetry. Therefore it is assumed for this study that evolution has proceeded toward greater degree of symmetry in ascospore form.

Character C. *Appendage morphology.*

Two states: plesiotypic, appendages thick-walled, multicellular; apotypic, appendages thin-walled or absent. Loss or reduction of peridium is accompanied by similar changes in appendages which are outgrowths of the peridium.

Character D. *Spiral hyphae.*

Two states: plesiotypic, helices absent; apotypic, helices present. In *Ajellomyces*, the specialized parasitic member of the Onygenales, helices are a significant feature of the peridium.

Character E. *Pathogenic abilities.*

Two states: plesiotypic, saprophytic; apotypic, parasitic. Parasitism is considered an advanced specialization in most groups of fungi.

Character F. *Pigmentation.*

Two states: plesiotypic, ascomatal hyphae deeply pigmented; apotypic, pigments lacking or very pale. With increasing dependence upon animal burrows for meiospore protection there is a loss of pigmentation.

Character G. *Ossiform cells.*

Two states: plesiotypic, ossiform cells present but with one central

Figure 3.2 PHENOGRAM DISPLAYING MAJOR CHARACTER STATES FOR DISTINGUISHING THE GENERA OF THE KERATINOLYTIC ONYGENALES (Arthrodermataceae and Onygenaceae).

LEGEND

1. keratinolytic.

2. ascospore walls pitted.

3. ascospore walls smooth.

4. peridia hyphal.

5. peridia membranous or pseudoparenchymatous.

6. ascospore shape oblate-convex.

7. ascospore shape oblate-discoid.

8. ascospore pits small and/or shallow.

9. ascospore pits broad and/or deep.

10. ascospore shape spherical to allantoid.

11. ascospore shape oblate.

12. peridium membranous

13. peridium of yellow, thick-walled, irregular, curved cells.

14. peridium of ±thick-walled, straight and or parallel-walled cells.

15. ascospores yellow to brown or violet.

16. ascospores allantoid or cylindrical.

17. reticulothecium of ossiform cells.

18. dimorphic (deep pathogens).

19. appendages well differentiated.

20. punctae evenly distributed over ascospore wall surface.

21. outer cells of peridium reticulothecial; inner cells forming a membrane.

22. outer cells of peridium ossiform with one deep constriction.

23. outer cells of peridium ossiform with one to three shallow constrictions.

24. stat. conid. mostly intercalary arthroconidia.

25. stat. conid. mostly terminal aleurioconidia; spirals present on (or constituting) the peridium.

26. peridial cells undifferentiated from vegetative cells; appendages lacking.

27. peridial cells disarticulating at maturity into irregular shapes.

28. peridial cells long and curved; not disarticulating at maturity.

29. peridial cells thick-walled and with uncinate appendages.

30. peridial hyphae rather thin-walled, tuberculate, constricted at septa.

31. ascospores hyaline, less than 3$\mu$m diam.

32. reticulothecium poorly formed (at least in culture); appendages absent.

33. reticulothecium well-developed; appendages usually distinctive.

34. reticulothecium well-developed; appendages pectinate and/or long, tapering, thick-walled hyphae.

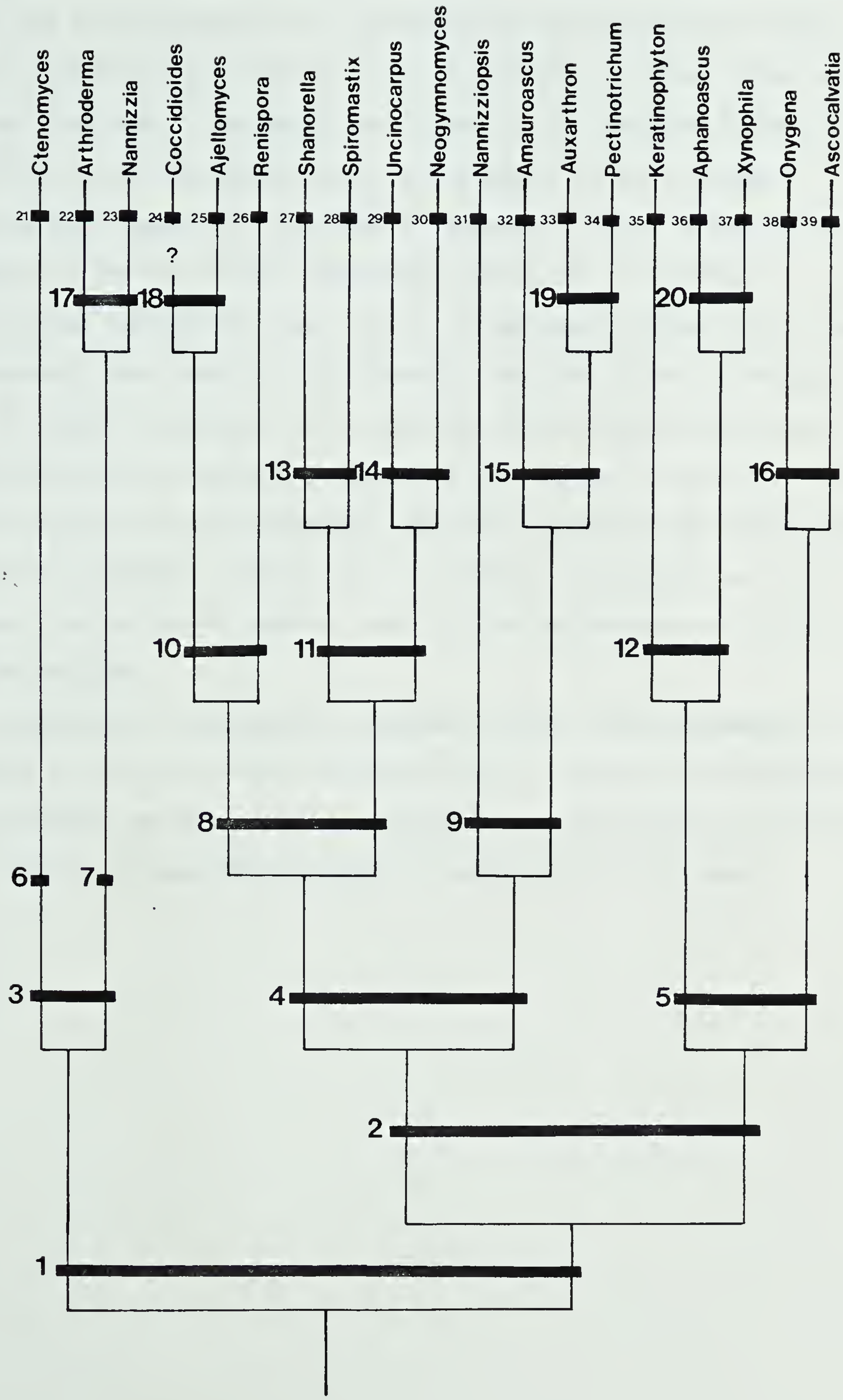
35. ascospores with punctate equatorial bands.

36. ascomata formed separately and lacking tomentose layer.

37. ascomata formed within a dense tomentum or stroma.

38. fruiting bodies stromatic, stipitate.

39. fruiting bodies stromatic, sessile.


Ctenomyces
Arthroderma
Nannizzia
Coccidioides
Ajellomyces
Renispora
Shanorella
Spiromastix
Uncinocarpus
Neogymnomyces
Nannizziopsis
Amauroascus
Auxarthron
Pectinotrichum
Keratinophyton
Aphanoascus
Xynophila
Onygena
Ascocalvatia
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constriction; asymmetrical; apotypic, ossiform cells with one to three symmetrical constrictions. Evolution proceeds toward symmetry.

From this brief discussion it is apparent that the evolutionary distance between *Ctenomyces*, and *Nannizzia* and *Arthroderma* is rather great. As mentioned previously, undescribed taxa remain to be analysed. Some of these may provide some intermediate steps and branches in this phylogeny.

One particular benefit of this type of analysis is that it prepares the investigator to find or expect intermediate forms, as for example a smooth-spored, keratinolytic taxon with a membranous peridium. With this type of preparation *Keratinophyton*, (Onygenaceae) assumes special significance. This genus has oblate ascospores with a punctate band encircling the equator. This intermediate form of ascospore sculpturing may suggest a connection between the smooth-spored Arthrodermataceae and the punctate-spored Onygenaceae. Looking for correlating evidence, we find that *Keratinophyton* can form two-celled conidia which resemble some of the phragmoconidia found in the Arthrodermataceae.

The occurrence of keratinolytic enzymes provides strong evidence for monophyly in this group. With continued work in isolation and description of new keratinolytic species, detailed phylogenetic reconstructions may become a useful addition to determining taxonomic relationships in this order.

Figure 3.3. Wagner tree illustrating a phylogenetic reconstruction for the Arthrodermataceae.

LEGEND

Ar *Arthroderma.*

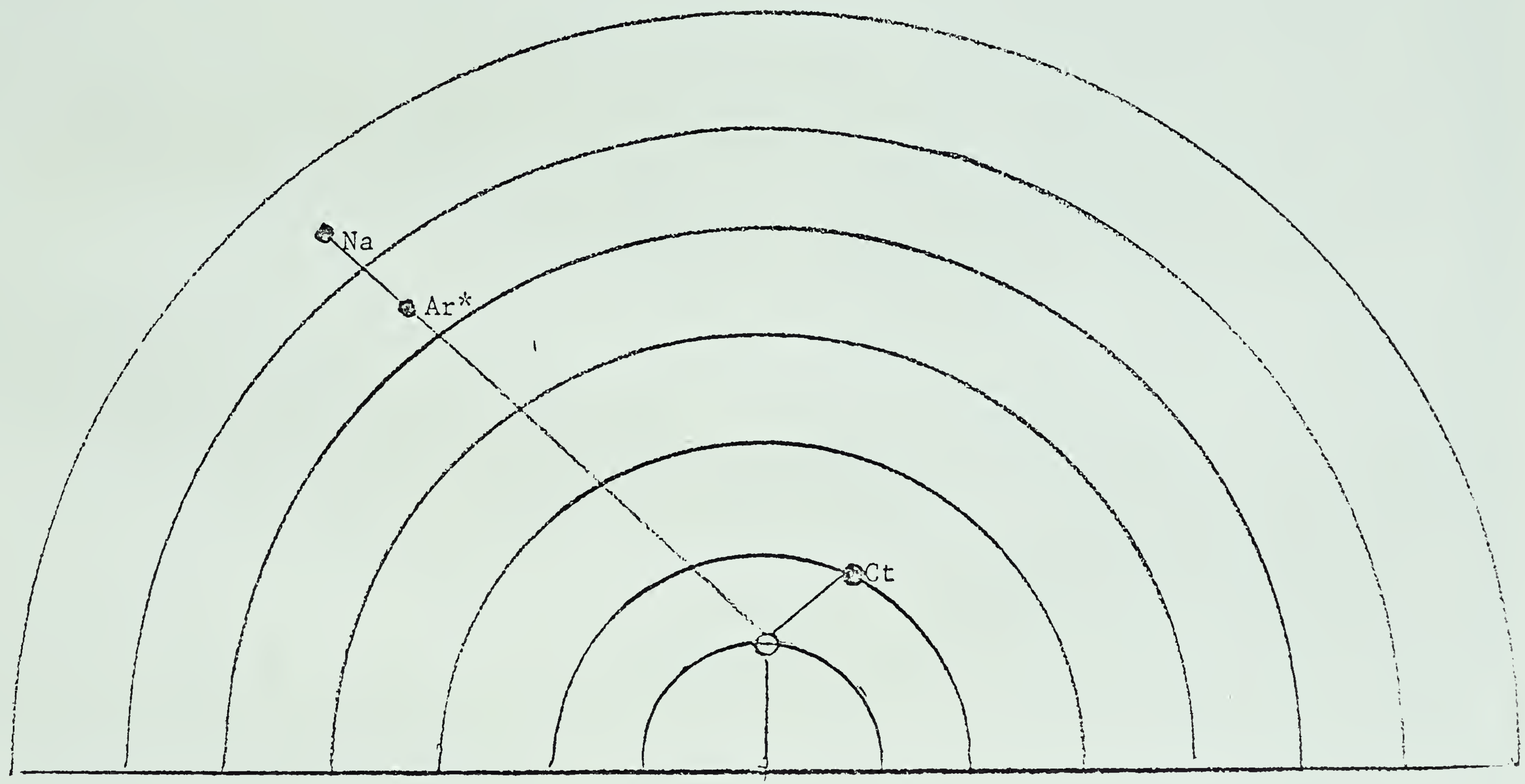
Ct *Ctenomyces.*

Na *Nannizzia.*

● Existing or known genus.

O Unknown or preexisting genus.

Table 3.9 gives characters used to construct this tree.




* With this analysis, Arthroderma is a paraphyletic group and thus, cladistically, has no validity.

Plate 3.1.

**a** *Gymnoascoideus petalosporus* (UAMH 1665) (Gymnoascaceae). Smooth, oblate ascospores in typical petaloid arrangement. X12500.

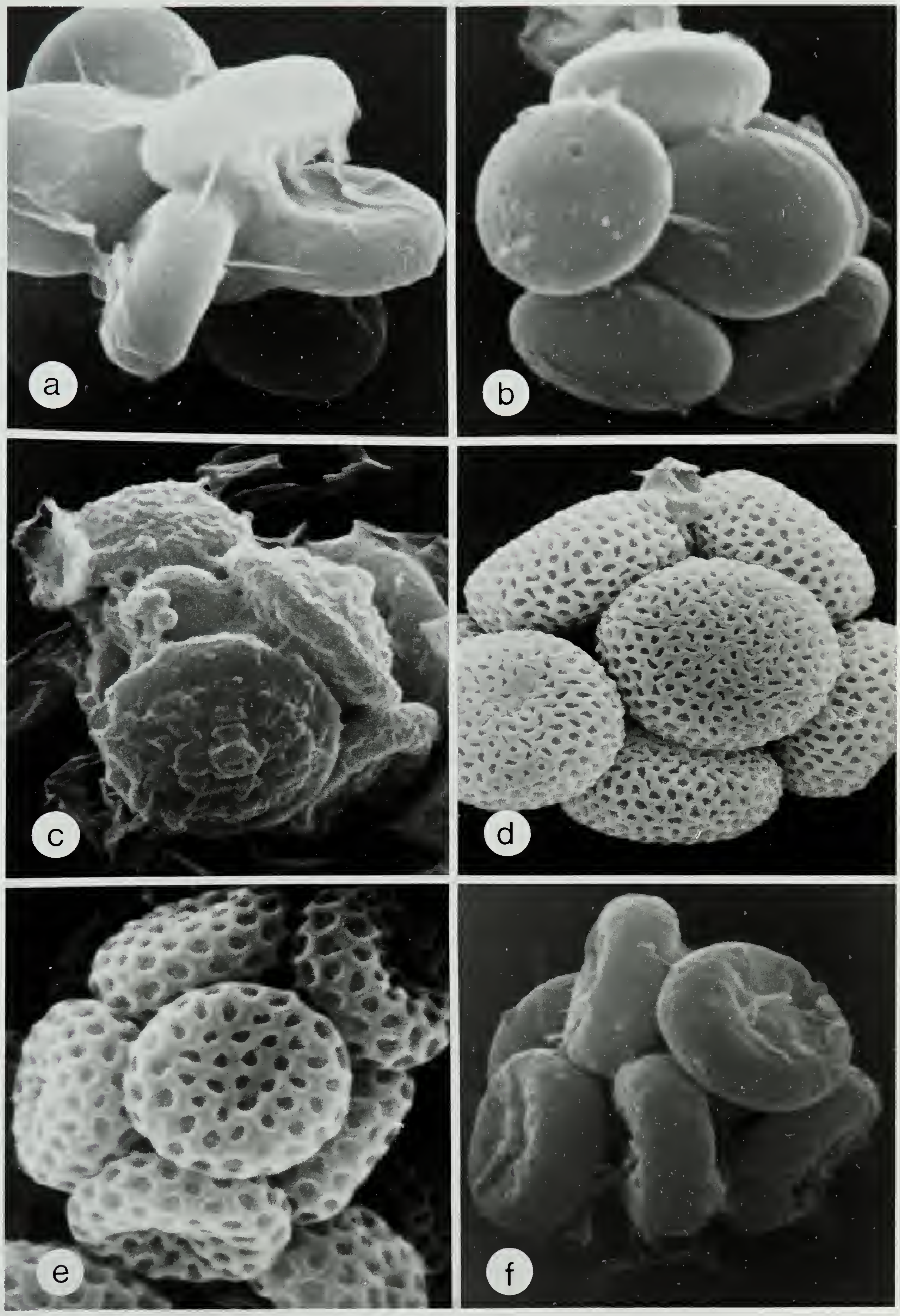
**b** *Gymnoascus reessii* (UAMH 1604) (Gymnoascaceae). Smooth, oblate ascospores remaining conglobate following dissolution of ascus membrane. X10500.

**c** *Gymnascella dankaliensis* (UAMH 3552) (Gymnoascaceae). Irregular-walled ascospores with polar and equatorial thickening. X7250.

**d** *Xynophila mephitalis* (TRTC HOLOTYPE) (Onygenaceae). Conglobate ascospores oblate with numerous irregular pits. X7000.

**e** *Auxarthron conjugatum* (UAMH 3156) (Onygenaceae). Conglobate, pitted, oblate ascospores; polar faces slightly concave. X14000.

**f** *Gymnascella aurantiaca* (TRTC A65C) (Gymnoascaceae). Smooth, oblate ascospores; polar faces concave with slight central bulge. X9500.


a
b
c
d
e
f

CHAPTER 4

## ARTHRODERMATACEAE

Arthrodermataceae Locquin, 1974, ex Currah

Typus *Arthroderma* Berkeley, 1860.

*Ascocarpi nivei, gilvi vel fulvi, globosi, minus 1000um diam., appendiculi exclusi. Ascosporae hyalinae ad gilvae, minutae, levae, oblati, minus 4um diam. Asci subglobosi vel globosi, tenues parietes, transparentes, octospori, minus 7um diam. Hyphae peridii pallido-flavae, septatae, uncinatim ramosae; cellulae ossiformae, brevae aut elongatae; raro textura epidermoidea. Appendicula helicalia septata, parietes leves; aut hyphae elongatae attenuatae; aut hyphae elongatae, crasso-parietales et pectinatae. Heterothallicus. Stat. conid: Chrysosporium, Microsporum aut Trichophyton.*

**Ascomata:** white, pale yellow to yellowish brown, globose, <1000*u*m diam. excluding appendages. **Ascospores:** hyaline to pale yellow, small, smooth, oblate, <4*u*m diam. **Asci:** subglobose to globose, thin-walled, transparent, 8-spored, <7*u*m diam. **Peridial hyphae:** pale yellow, septate, uncinately branched; cells ossiform, short or elongate, rarely forming pseudoparenchyma. **Appendages:** thin-walled, septate and helical and/or elongate and tapered; or thick-walled and pectinate. **Anamorphs:** *Chrysosporium Microsporum* or *Trichophyton.*

This family includes both saprophytic species and dermatophytes, fungi that live as parasites on the skin, hair or nails of man and other animals (many species of *Arthroderma* and *Nannizzia*). *Ctenomyces serratus* has not been shown to be parasitic and is a saprophyte found chiefly in soil and on shed feathers. Key characters for the 3 genera in the family are presented in Table 4.1.

Ajello (1968) provides a review of the taxonomic problems with the anamorph names of the dermatophytes. An historical account of the relationship between the teleomorphs and their anamorphs may be found in Ajello (1971). Otcenasek and Dvorak (1975) review an ecological classification which divides the species among the groups designated: "geophilic," "anthropophilic," and "zoophilic" (respectively non-parasitic saprophytes usually found in soil, pathogens of man and pathogens of other animals, respectively). Isolation from soil is

effected by using sterilized hair as bait. Isolation from clinical sources is accomplished by using a variety of techniques and selective media (McGinnis, 1980).

Distinguishing taxa within *Arthroderma* and *Nannizzia* in some cases requires morphological information from both teleomorphs and anamorphs, and sometimes mating tests are essential to confirm species identification. For species of medical importance, anamorphs have been used for identification. Both genera exhibit species complexes that so far can only be distinguished on the basis of mating behaviour with known testor strains. There is some evidence that morphology of the ossiform cells of the peridial hyphae of these genera may yield some useful taxonomic information. This would probably be a profitable aspect to pursue in future research. Variation in morphology and cultural characters within some species of both genera, coupled with the difficulties of using morphological information for distinguishing between "biological species," pose serious problems for routine identification of species from saprophytic sources.

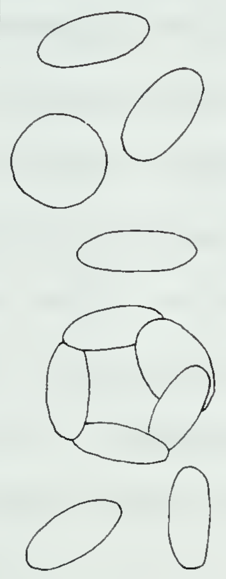
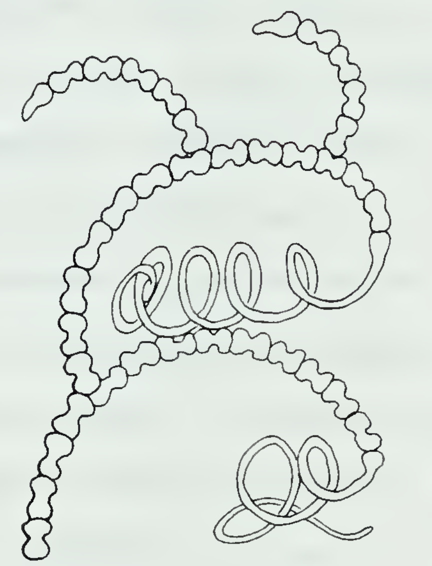
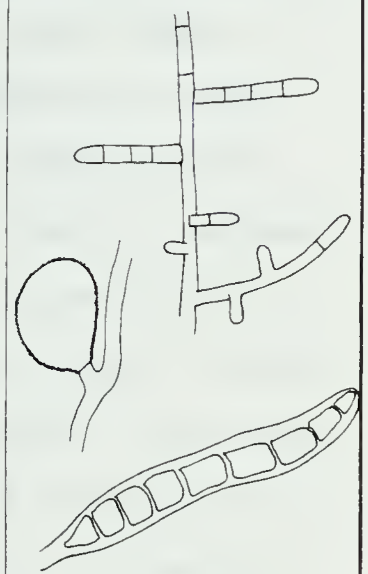
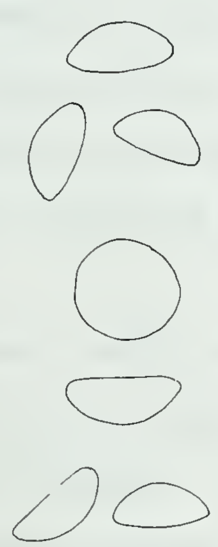
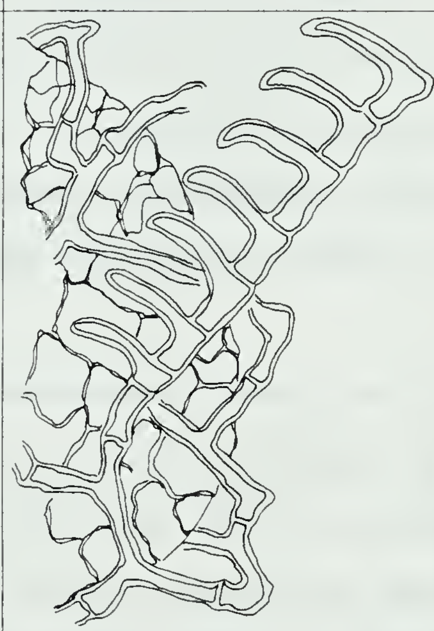
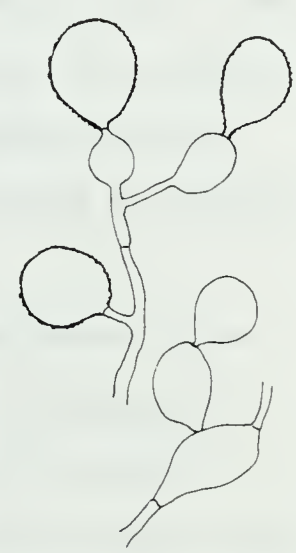
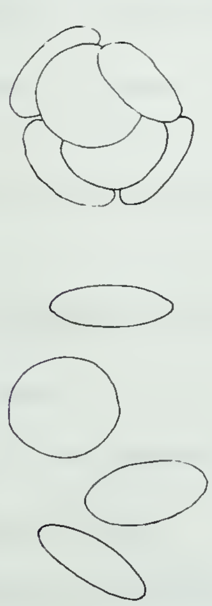
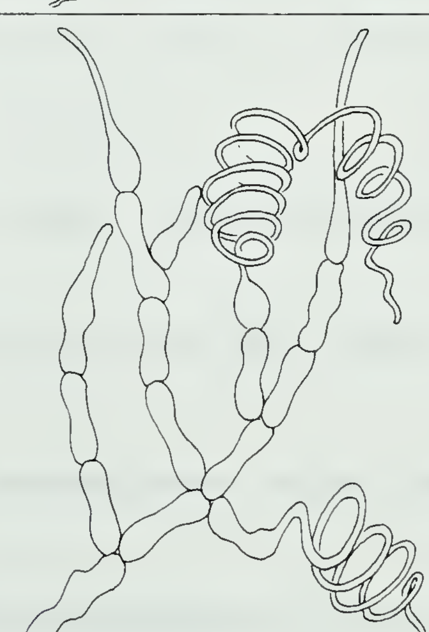
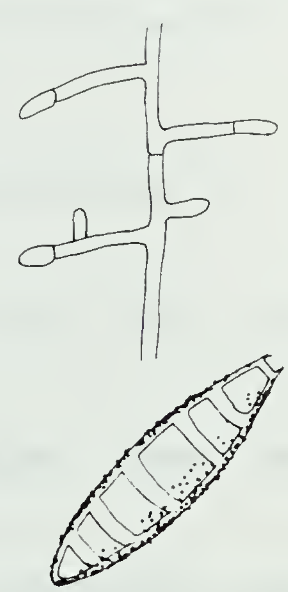
While the close morphological relationship of *Nannizzia* to *Arthroderma* is obvious, some justification for placing *Ctenomyces* in the Arthrodermataceae is required. In addition to having tiny, smooth-walled, more or less oblate ascospores, the pectinate appendages of *Ctenomyces* appear to be structures homologous to the ossiform cells of *Arthroderma* and *Nannizzia* (fig. 4.1). In each case the cell is swollen adjacent to the septum, although in *Ctenomyces* the swelling (forming a hook) occurs only at one end of the cell. In *Arthroderma* and *Nannizzia*, both ends of the cell are swollen. Since these protrusions occur toward the median portion of the cell rather than over the septum, these formations are not comparable to the "knuckle joints" found in *Auxarthron* and *Gymnoascus*. Both the ossiform cells and cells of the pectinate appendage are thick-walled and roughened, and comparable in length and in width of the body of the cell. The *Chrysosporium* state of *Ctenomyces serratus* is strikingly similar in morphology to the *Chrysosporium* state of *Arthroderma tuberculatum*, and the free conidia of the two are easily confused. There is particularly a problem in distinguishing the species on natural substrata, especially

if the material is old and dried. In culture, slides can be prepared which show the differences in the conidiophores of the two taxa: the conidia of *A. tuberculatum* have straight pedicels while the conidia of *C. serratus* have swollen pedicels.

Difficulties in distinguishing between (and among) some taxa in this family have prompted taxonomic investigations in areas other than morphology, particularly for the medically important species. The application of modern taxonomic methods to the systematics of the Arthrodermataceae has been relatively intense when compared to other families in the Onygenales. These studies have involved analysis of proteins (Shechter, 1973; Shechter *et al.*, 1968 a,b; Sekhon *et al.*, 1974; Sekhon and Carmichael, 1976), lipids (Kish and Jack, 1974; Swenson and Ulrich, 1980; Vincent, 1978), carbohydrates (Noguchi *et al.*), antigenic compounds (Andrieu *et al.*, 1966; Christiansen and Svejgard, 1976; Grappel *et al.*, 1970; Philpot, 1978), and pyrolytic components (Brosseau and Carmichael, 1978; Carmichael *et al.*, 1973; Sekhon and Carmichael, 1971, 1972, 1973). Difficulties in obtaining standardized culture material, and technical problems with the methods themselves, have limited the taxonomic value of these investigations. In addition, morphological species complexes seem no less confusing given the added data from these techniques.

TABLE 4.1

GENERA OF ARTHRODERMATACEAE

| Genus | Ascospores | Peridia and Appendages | Anamorphs |
|---|---|---|---|
| Arthroderma |  |  |  |
| Ctenomyces |  |  |  |
| Nannizzia |  |  |  |

## **ARTHRODERMA** Berkeley, 1860

Outlines of British Fungology p. 357.

**Type species:** *Arthroderma curreyi* Berkeley.

**Ascomata:** off-white to cream, pale yellow or buff, globose, 200-950*u*m diam., excluding appendages. **Ascospores:** hyaline, yellow in mass, oblate, smooth, 1.5-2.5 x 2.5-3.5*u*m. **Asci:** hyaline, globose, subglobose or ovoid, 8-spored, usually <7*u*m diam., evanescent. **Peridial hyphae:** hyaline to pale yellow or buff, septate, branched either dichotomously or uncinately; component cells ossiform, usually either symmetrically or asymmetrically constricted, not normally longer than 10-14*u*m, walls moderately thick-walled, minutely to densely asperulate or echinulate. **Appendages:** septate, thin-walled, smooth, long, slender, with helical tips. **Thallism:** heterothallic (possible exceptions in *Arthroderma curreyi* and *Arthroderma ciferrii*). **Anamorph:** *Chrysosporium* or *Trichophyton.*

**Notes:** Thirteen species are discussed by Padhye and Carmichael (1971), and are divided into 2 groups based on occurrence of macroconidia. Very similar to *Nannizzia* teleomorphs of *Microsporum* but generally distinguished from this genus by the shape of the cells of the peridial hyphae as well as by anamorph characters.

**References:** Benjamin, 1956 (*Arthroderma curreyi* and classification of the genus with respect to *Ctenomyces*); Howard, 1983 (Summary of pathogenic species); Padhye and Carmichael, 1971 (Key and line drawings); Pore and Plunkett, 1965 (Biological species concept); Rebell and Taplin, 1970 (Identification manual for dermatophytes); Richardson and Watling, 1969 (Line drawings of ascospores and peridium); Visset, 1973 (SEM).

*Arthroderma benhamiae* Ajello and Cheng, 1967 Sabouraudia **5**:230-232 FIG 1-14.

**Type material:** HOLOTYPE *(cultura desiccata)* **CDC** B765d (TM20 from human X TM17 from dog).

**Anamorph name:** *Trichophyton mentagrophytes* (Robin) Blanchard, 1896. (see Rebell and Taplin (1970))

**Ascomata:** off-white, 250-450*u*m. **Ascospores:** 1.2-1.8 x 2.5-2.8*u*m. **Asci:**

3.6-6.0 x 4.2-7.2*um*. **Peridial hyphae:** hyaline, dichotomously branched, distal branches curving over the ascoma ; cells echinulate, asymmetrically constricted, 4.5-5.2 x 8.0-12*um*. **Appendages:** elongate, smooth-walled, tapering at apex, 60-200*um*; smooth-walled helices. **Anamorph:** Microconidia clavate to subglobose, mostly almost spherical, borne mostly in grape-like clusters from the sides of inflated conidiogenous hyphae that are richly branched at right angles. Macroconidia clavate, 3-5 septate, smooth-walled, 6.0-8.0 x 20-50*um*; rare, or in "granular forms" numerous. (Morphological variation in this anamorph has caused numerous descriptions of distinctive varieties under many species names. These are listed in Padhye and Carmichael, 1971 and Howard, 1983.) **In culture:** [UAMH 2823] CER 14/25°C white, closely appressed, velvety, radiately fibrillose; reverse pale brownish yellow. DSA 42/25°C white, subgranular, margin ragged; reverse uncolored to pale yellow. PYE 21/25°C white to pale cream, thick and felty, radiately fibrillose; reverse reddish to chestnut brown.

**Notes:** Microconidia provide the most reliable diagnostic feature for this species. Common agent of numerous types of dermatophytoses in man and other animals. Worldwide in distribution.

**Material examined:** **UAMH** 2823 (-SAC from CDC X798, cultured from holotype (1967).

*Arthroderma ciferrii* Varsavsky and Ajello 1964 Riv. Patol. Veg. **4**:358-359 FIG 1-6.

**Type material:** HOLOTYPE *(cultura desiccata)* **CDC** B590 (soil from hog pens, Arkansas).

**Anamorph name:** *Trichophyton georgiae* Varsavsky and Ajello *op. cit.* =*Chrysosporium georgii* (Varsavsky and Ajello) Van Oorschot, 1980.

**Ascomata:** pale ochraceous-salmon to pale vinaceous-brown with age, 450-800*um* diam. **Ascospores:** 1.5-2.8 x 2.5-3.5*um*. **Asci:** 4.8 x 6.0*um*. **Peridial hyphae:** hyaline, uncinately branched with curled ends; cells symmetrical or asymmetrical, 7.0-8.5 x 8.0-12*um*, (4.2*um* at constrictions), densely asperulate. **Appendages:** slender, smooth-walled, lateral or terminal helices, and slender, smooth-walled, tapered hyphae, 60-96*um* long. **Anamorph:** Conidia

variable, elongate, clavate, pyriform, subglobose, lateral or terminal, pedicellate or sessile, smooth-walled, 0-3 septate, 2.0-2.5 x 4.0-6.5*um*. **In culture:** [UAMH 2534]. CER 15/25°C buff with vinaceous-brown sectors, felty to granular; reverse pale yellow and vinaceous-brown. DSA 42/25°C sparse white growth; reverse orange to yellow. PYE 28/25°C vinaceous to vinaceous-brown, powdery to granular; reverse brown with irregular spots of dark red or vinaceous-brown.

**Notes:** No growth at 37°C, non-pathogenic. Also recovered from soil and Opossum hair, Georgia.

**Material examined: UAMH** 2543, type strain as cited.

*Arthroderma cuniculi* Dawson, 1963 Sabouraudia **2**:187 FIG 2a-h.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** 96243 (rabbit burrow soil, Scotland).

**Anamorph name:** *Chrysosporium* state of *Arthroderma cuniculi*.

**Ascomata:** pale yellow, 160-380*um* diam. **Ascospores:** 1.5-2.8 x 2.5-3.0*um*. **Asci:** 3.7-5.0 x 4.0-5.4*um*. **Peridial hyphae:** pale yellow, uncinately branched to the outside of the main branch; cells 3.0-6.0 x 5.8-11*um*, echinulate, becoming 3-4 condylate at maturity (protuberances up to 3.5*um* long and 1.2-2.7*um* at the base develop at each end). **Appendages:** septate, smooth-walled, helices with 4-16 gyres, terminal or lateral. **Anamorph:** Conidia variable, hyaline, clavate to pyriform, short-pedicellate, in grape-like clusters, smooth-walled, 1-3-celled, 1.2-2.0 x 2.0-7.0*um*. **In culture:** [UAMH 1788] CER 14/25°C pale rusty yellow, granular, radiately fibrillose; reverse yellow. DSA 14/25°C buff colored, thick, localized growth; reverse white. PYE 14/25°C pale yellow to buff, powdery; reverse yellow to brown.

**Notes:** No growth at 37°C. Non-pathogenic saprophyte found in soil and dung. Further reports of this species from animal hair, reptile scales, bird pellets, nests and feathers are referenced in Domsch, Gams and Anderson (1980).

**Material examined: UAMH** 3203/soil/California, coll. Carmichael (1969).; 3204/leaves mixed with soil/California, coll. Carmichael (1969); 3586/soil/Manitoba, from J. Reid, Univ. of Manitoba as UM 75.

*Arthroderma curreyi* Berkeley, 1860 Outlines of British Fungology 357.

PL 4.1a,c

**Type material:** None preserved.

≡*Illosporium curreyi* (Berkeley) Saccardo, Sylloge Fungorum **4**:660, 1886.

=*Arthroderma xylophilum* Von Hohnel (see Rehm, Ann. Myc. **3**:416, 1886).

**Anamorph name:** *Chrysosporium* state of *Arthroderma curreyi*.

**Ascomata:** white to pale yellow, discrete to confluent, 100-450*u*m diam. excl. appendages. **Ascospores:** 1.2-2.5 x 2.5-3.5*u*m. **Asci:** 4.0-5.0 x 5.0*u*m. **Peridial hyphae:** hyaline, radiating from the ascoma in a spiral pattern, dichotomously branched, (usually to outside of spiral); cells symmetrical or asymmetrical, 2.0-4.0 x 3.0-9.0*u*m, minutely to densely asperulate. **Appendages:** terminal helices. **Anamorph:** Conidia lateral, sessile to short pedicellate, smooth to rough-walled, clavate to pyriform, unicellular, 1.5-2.0 x 2.5-6.0*u*m. **In culture:** [UAMH 4768 (dung, southern Alberta)]. CER 21/25°C pale cream, slightly granular to felty, radiate; reverse uncolored. DSA 42/21°C yellowish cream granular knots of mycelium; reverse uncolored. PYE 21/25°C white to pale cream to buff, flat, floccose; reverse pale yellow to buff.

**Notes:** Cosmopolitan saprophyte of discarded keratinous materials (hair, feathers, horn etc.). Domsch, Gams and Anderson (1980) reference isolations from soil and leaf litter. No growth at 37°C. Pugh (1964) notes that it is probably not a true soil inhabitant because it cannot grow on unsterilized soil. Recovery rate from the feathers of trapped birds was 14%.

**Material examined:** as *"Ctenomyces serratus"*: **FH** Thaxter, 183/feather culture/loc.? (1916); Thaxter 219/horn/Massachusetts (1900); Thaxter 300 (also at **TRTC**/manure/Maine (1929); Thaxter 506/skunk dung/Maine. as *"Ctenomyces xylophilus"*: **FH, HBG, MPU, PACA, TRTC, S** Von Hohnel 1625/decayed wood of *Fagus*/Germany (1902). as *"Arthroderma* sp.": as *Arthroderma curreyi*: **NY** Pugh/?/loc., from Orr (1965); **RSA** 186/feathers/Massachusetts, coll. Benjamin (1951). **UAMH** 3171/soil/Ohio, coll. Kurup, Ohio State Univ. #SL2 (1969); 3617/skin/Louisiana, Tulane Friedman Univ. School of Medicine, New Orleans 5381-H (1973); 4768/dung/Alberta, coll. Currah (1983).

*Arthroderma flavescens* Rees, 1967 Sabouraudia **5**:206-207 FIG 1a-g.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** 117342 (feathers, south eastern Queensland).

**Anamorph name:** *Trichophyton flavescens* Padhye and Carmichael, 1971.

**Ascomata:** pale buff, darker with age, 450-650*um* diam. **Ascospores:** 1.8-2.0 x 3.2-4.0*um*. **Asci:** 4.8-7.5 x 5.9-8.3*um*. **Peridial hyphae:** hyaline, with 2 inwardly curving branches arising from some apices; cells asymmetrical, echinulate, 3.0-4.8 x 11-17*um*. **Appendages:** smooth-walled, septate, terminal, helical hyphae, 2.7-4.8*um* wide at the base with up to 22 gyres. **Anamorph:** Microconidia lateral or terminal, smooth, thin-walled, sessile or short-pedicellate, unicellular or occasionally 2-celled, pyriform, ovoid, 4.0-8.0 x 5.0-16*um*. Macroconidia numerous, hyaline, 2-6-septate, smooth, thin-walled, cylindrical with rounded apices, 8.0-14 x 26-86*um*. **In culture:** [UAMH 2933]. CER 14/25°C pale creamy tan; reverse uncolored. DSA 42/25°C white, scant granular growth; reverse uncolored. PYE 14/25°C white to pale buff, dense and felty; reverse bright yellow to yellow-brown.

**Notes:** No growth at 37°C. Evidently not pathogenic.

**Material examined:** **UAMH** 2933/feathers/India, from CMI 117340 (1968).

*Arthroderma gertleri* Bohme, 1967 Mykosen **10**:251 FIG 1ab, 2ab and 3.

**Type material:** HOLOTYPE *(cultura desiccata)* Mykothek der Univ-Hautklinik, Berlin Nr. 307 (soil, Germany).

**Anamorph name:** *Trichophyton vanbreuseghemii* Rioux, Jarry and Juminer, 1964. (see Rebell and Taplin (1970))

**Ascomata:** pale yellow, 200-600*um* diam. **Ascospores:** 1.5-2.0 x 2.0-2.8*um*. **Asci:** 4.0 x 5.0*um*. **Peridial hyphae:** hyaline, uncinately branched; cells asymmetrical, (occasionally symmetrical), echinulate. **Appendages:** terminal, septate helices varying in length and number of gyres. **Anamorph:** Microconidia pyriform, subglobose, ovoid, thin-walled, unicellular, sessile or on short pedicels, lateral or terminal, 1.5-2.5 x 2.0-7.0*um*. Macroconidia numerous, thin-walled, smooth, cylindrical, multiseptate, borne singly, 6.0-8.0 x 30-55*um*. **In culture:** [UAMH 2620]. CER 14/25°C pale creamy white, cottony, margin fimbriate;

reverse bright yellow. DSA 42/25°C scant, yellowish cream, granular, radiately fibrillose, reverse bright yellow. PYE 14/25°C white to creamy white to yellowish buff, radially grooved, velvety; reverse cream to pale buff.

**Notes:** Rare dermatophyte. Possibly cosmopolitan (see Howard, 1983).

**Material examined: UAMH** 566/soil/Alberta, coll. Carmichael (1956); 2620/soil/Germany, -SAC from Bohme (1966); 2998/soil/Alberta, coll. Padhye (1968).

*Arthroderma gloriae* Ajello, 1967 Mycologia **59**:257 FIG 1-12.

**Type material:** HOLOTYPE *(cultura desiccata)* **CDC** X778d (soil with keratin, Arizona and N.Mex).

**Anamorph name:** *Trichophyton gloriae* Ajello, *op. cit.*

**Ascomata:** pale yellow, 250-450*um* diam. **Ascospores:** 1.5-2.0 x 2.0-2.5*um*. **Asci:** 3.5 x 4.6*um*. **Peridial hyphae:** hyaline, uncinately branched; cells echinulate symmetrically constricted, mostly 5.0 x 7.5*um*. **Appendages:** moderately slender, thin-walled, pointed, 150*um* long. **Anamorph:** Microconidia pear-shaped, sessile or short stipitate, 1.5-2.5 x 1.5-6.0*um*. Macroconidia numerous, usually in clusters of 4-30, cylindrical, 1-10 septate, smooth, walls to 1*um* thick, 3.0-7.0 x 9.0-60*um*. **In culture:** [UAMH 2820]. CER 14/25°C ochre to yellow, granular, radiate; reverse pale yellow. DSA 42/25°C cream-yellow sparse growth; reverse uncolored. PYE 14/25°C ochre, felty to granular; reverse yellow with yellow-brown centre.

**Notes:** Yellow pigment more pronounced at 37°C. Non-pathogenic.

**Material examined: UAMH** 658/soil/New Mexico, (1959); 2820, +SAC from CDC X779 (1967).

*Arthroderma insingulare* Padhye and Carmichael, 1972 Sabouraudia **10**:49-50 FIG 1-7.

**Type material:** HOLOTYPE *(cultura desiccata)* **UAMH** 3443 (soil and chicken feathers, Alberta).

**Anamorph name:** *Trichophyton terrestre* Durie and Frey, 1957 (complex). (see Rebell and Taplin (1970))

**Ascomata:** white to pale yellow, 250-500*um*. **Ascospores:** 1.8-2.2 x

2.5-3.0*um*. **Asci**: 3.5-5.0 x 4.0-6.0*um*. **Peridial hyphae:** hyaline to pale yellow; cells asymmetrically constricted, 5.0-6.0 x 8.0-12*um*, echinulate. **Appendages**: smooth-walled, septate helices varying in length and number of turns. **Anamorph:** Microconidia clavate to cylindric, borne on undifferentiated hyphae, sessile or on short pedicels, 1.5-3.0 x 3.0-6.5*um*. Macroconidia clavate to cylindrical, smooth-walled; (2-celled conidia form in large numbers). **In culture:** [UAMH 3442]. CER 28/25°C grayish yellow to buff, slightly floccose; reverse bright yellow. DSA 42/25°C patchy off-white growth; reverse uncolored. PYE 21/25°C pale buff, floccose, concentrically zonate; reverse yellowish brown.

**Notes:** No growth at 37°C. Differentiated from *Arthroderma quadrifidum* solely on mating reactions.

**Material examined: UAMH** 3438, 3439/soil/Alberta, Padhye (1971); 3440/chicken feathers/Alberta, Padhye (1971); 3442 -SAC from 3438 X 3440 (1971); 3455/human hair/Guatemala from Univ. de San Carlos de Guatemala "68C" (1971).

*Arthroderma lenticularum* Pore, Tsao and Plunkett, 1965 Mycologia **57**:970-971 FIG 1-3.

**Type material:** HOLOTYPE *(cultura desiccata)* **NY** Pore, Tsao and Plunket #502 (soil on animal keratin, California).

**Anamorph name:** *Trichophyton terrestre* Durie and Frey, 1957. (complex). (see Rebell and Taplin (1970))

**Ascomata:** pale buff, 300-600*um*. **Ascospores:** 1.5-2.5 x 2.2-3.0*um* diam. **Asci:** 4.0-4.8 x 5.0-5.6*um*. **Peridial hyphae:** pale yellow, uncinately branched to outside of main hypha; cells symmetrically constricted, echinulate, 5.5-8.5 x 7.0-10*um*. **Appendages**: terminal, septate helices. **Anamorph:** Microconidia elongate, pyriform, single or in groups, 1.5-3.5 x 3.0-6.5*um*. Macroconidia cylindrical or rarely clavate, smooth, thin-walled, sessile, 2-6-celled, 4.0-5.0 x 8.0-52*um* with intermediate forms. **In culture:** [UAMH 2931]. CER 14/24°C pale yellow, flat; reverse yellow-brown. DSA 41/25°C white, feathery; reverse uncolored. PYE 14/25°C grayish cream, thick felty, radiately zonate; reverse brownish yellow.

**Notes:** Colonial morphology indistinguishable from *Arthroderma quadrifidum*; both have *Trichophyton terrestre* anamorphs. Distinction based on peridial hyphae: *Arthroderma lenticularum* has symmetrical ossiform cells while *Arthroderma quadrifidum* has asymmetrical ossiform cells.

**Material examined: NY** Pore, Tsao and Plunket #502/(type as cited). **UAMH** 2931 +SAC from CMI 113772.

*Arthroderma multifidum* Dawson, 1963 Sabouraudia **2**:189 FIG 3a-i.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** 94207 (rabbit burrow soil, Scotland).

**Anamorph name:** *Chrysosporium* state of *Arthroderma multifidum*.

**Ascomata:** pale yellow to yellow-buff, globose, 250-550*u*m diam. excl. appendages. **Ascospores:** 1.5-3.0 x 2.5-3.5*u*m. **Asci:** 4.5-6.0 x 5.0-6.5*u*m. **Peridial hyphae:** pale yellow, uncinately branched, usually to outside of main hypha; cells 4.0-6.5 x 5.8-13*u*m, echinulate, at maturity with 4-8 protuberances up to 1.5-2.5 x 5.0*u*m, creating a T or Y shape. **Appendages:** septate, smooth, helices, terminal on peridial hyphae. **Anamorph:** Conidia short-pedicellate or sessile, pyriform, subglobose to obovoid, smooth to sparsely rough-walled, 0-2-septate, walls 0.5-1.0*u*m thick; borne laterally on undifferentiated hyphae. 6.6-13 x 8.8-20*u*m. **In culture:** [UAMH 1787]. CER 14/25°C yellowish tan with green tinge, feathery; reverse bright yellow. DSA 42/25°C greenish ochre, granular; reverse tan. PYE 14/25°C sectored. 1. brownish tan, finely granular; reverse bright yellowish tan. 2. bright yellow, granular; reverse pale yellow.

**Notes:** Soil saprophyte; probably cosmopolitan. No growth at 37°C and no records of pathogenicity.

**Material examined: UAMH** 1977/pasture soil/Czechoslovakia, Kunnert, Palaky Univ. Olomouc CH 8 (1964); 1787 +SAC from type, obtained from C. O. Dawson, Glasgow (1963);2708/soil/Roumania, Alteras, Central Dermato Venerologic Bucharest #3 (1967); 2783/gopher burrow/Alberta, Remington, Edmonton (1967); 4600/soil/Spain, Guarro, Univ. of Barcelona, FFBA 340 (1982); 4766/bottom sediments of polluted pond/Poland, Ulfig, Katowice No 4 (1983).

*Arthroderma quadrifidum* Dawson and Gentles, 1961 Sabouraudia 1:55-56 FIG 2a-e.

FIG 4.1

**Type material:** **CMI?**

**Anamorph name:** *Trichophyton terrestre* Durie and Frey, 1957. (complex). (see Rebell and Taplin (1970))

**Ascomata:** pale buff, 400-700*u*m diam. **Ascospores:** 0.9-2.2 x 1.8-3.0*u*m. **Asci:** 3.5-5.0 x 4.0-6.0*u*m. **Peridial hyphae:** pale yellow, uncinately branched to outside of main hypha; cells 5.0-9.0 x 8.0-13.0*u*m, strongly echinulate, at maturity condylate on one face. **Appendages:** terminal or lateral, septate helices varying in length and number of gyres. **Anamorph:** Microconidia elongate, pyriform, single or in groups, 1.5-3.5 x 3.0-6.5*u*m. Macroconidia cylindrical or rarely clavate, smooth, thin-walled, sessile, 2-6-celled, 4.0-5.0 x 8.0-52*u*m. **In culture:** [UAMH 1686] CER 14/25°C white, granular; reverse uncolored. DSA 33/25°C ash-gray, dense in restricted patches; reverse uncolored. PYE 14/25°C gray to off-white, fluffy to powdery when dried, zonate; reverse reddish to yellow-brown.

**Notes:** First isolated from soil, hair of horse and wild rat; recovered from soil, Belgium (Ajello *et al.*, 1965), Galapagos Islands (Ajello, 1974) and probably cosmopolitan although Domsch, Gams and Anderson (1980) note that it may have a preference for subtropical and temperate zones. Reported from a wide range of substrates including soil, skin-scrapings and feathers; Dawson and Gentles have isolated it from a ring-worm lesion on a squirrel. Under experimental conditions it may cause infections (see Domsch, Gams and Anderson (1980)) otherwise it is not commonly pathogenic. No growth at 37°C.

**Material examined:** **UAMH** 544, 565/soil/Alberta, coll. Carmichael (1959); 669/lung of *Citellus richardsonii*/Alberta, coll. Carmichael (1960); 755/soil of pig yard/Alberta. 760/soil from chicken run/Alberta, coll. Carmichael (1960); 790/skin of human foot/Alberta, coll. Carmichael CP60-974 (1960); 824/hedgehog hair/New Zealand, Marples, Univ. of Otago (1960); 864/soil/Hungary, Georg (1961); 1328/badger soil/Alberta, coll. Carmichael, 18-8-ax; 1686/soil/Alberta, coll. Carmichael (1963); 2125/human foot/Alberta,

coll. Carmichael MY 2061-64 (1964); 2703/hair and skin scrapings from cat/Alberta, coll. Carmichael MY 3222 (1966).

*Arthroderma simii* Stockdale, Mackenzie and Austwick, 1965 Sabouraudia **4**:113-114 PL 1a-e, FIG 1 a,b.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CMI** 93944 (chicken, India).

**Anamorph name:** *Trichophyton simii* (Pinoy) Stockdale, Mackenzie and Austwick *op. cit.*

**Ascomata:** pale buff to buff, 200-700*u*m diam. **Ascospores:** 1.5-2.5 x 2.5-3.5*u*m. **Asci:** 5.0-6.7 diam.*u*m. **Peridial hyphae:** pale buff, up to 3 secondary branches arising from one cell, distal branches curve over ascoma; cells 3.0-4.5 x 13-21*u*m, ends giving rise to branches 5.0-7.5*u*m diam. Outermost branch cells asymmetrical, echinulate, 4.2-6.7 x 6.5-13*u*m. **Appendages:** slender, smooth-walled, septate helices. **Anamorph:** Microconidia more numerous with age, clavate to pyriform, 1.5-4.0 x 2.0-6.5*u*m, sessile to substipitate, in clusters. Macroconidia numerous, terminal on branched hyphae, hyaline, smooth-walled, fusiform to cylindrofusiform, 6.0-11 x 30-80*u*m, 4-10-sepate, constricted at septa with age to form thick-walled chlamydospores. **In culture:** [UAMH 2944]. CER 42/25°C grayish tan, felty; reverse buffy brown. DSA 42/25°C tan in localized felty patches; reverse uncolored. PYE 14/25°C white, cottony with yellowish brown patches; reverse pale reddish brown.

**Notes:** Helical hyphae moderately abundant on vegetative mycelium of old cultures. Grows at 37°C. Pathogenic to man, monkeys, dogs and poultry. Reported from India, Brazil and Nigeria. Kwon-Chung (1972) presents a study of incompatibility in this species.

**Material examined: UAMH** 2944 -SAC from CMI 98944 from poultry, India (1968).

*Arthroderma tuberculatum* Kuehn, 1960 Mycopathol. et Mycol. Appl. **13**:190 FIG 1-15.

**Type material:** HOLOTYPE *(cultura desiccata)* . **NRRL** (robin feathers, Illinois).

**Anamorph name:** *Chrysosporium* state of *Arthroderma tuberculatum*.

=*Myceliophthora* state of *Arthroderma tuberculatum fide* Van Oorschot,

1980.

**Ascomata:** creamy white to cream-yellow, 430-970*um* diam. **Ascospores:** 1.5-1.8 x 2.8-3.2*um*. **Asci:** 3.9-4.7 x 4.5-5.5*um*. **Peridial hyphae:** pale yellow, uncinately branched to the outside of main hypha; cells symmetrical or asymmetrical 6.0-7.0 x 10-27*um* (4.0*um* wide at constriction), densely asperulate. **Appendages:** slender, septate, hyaline, smooth-walled, terminal helices. **Anamorph:** Conidiaaseptate, terminal or lateral, short-pedicellate or sessile, subglobose, ovoid, pyriform with a thick, tuberculate wall, 7.0-10.0 x 10.0-15.0*um*. **In culture:** [UAMH 3181]. CER 28/25°C pale yellow, granular; reverse orange-tan. DSA 42/25°C white, sparse; reverse uncolored. PYE 7/25°C cream to pale yellow, granular to felty; reverse orange-tan.

**Notes:** Cosmopolitan. Isolated from soil, feathers, hairs, bird's nests, bat dung (see Domsch, Gams and Anderson (1980)) and onychomycoses (Rippon, 1974). No growth at 37°C.

**Material examined: UAMH** 1724/soil/British Columbia, coll. Carmichael (1963); 1967/soil/Argentina, Varsavsky EV&A (1964); 3147/finger lesion/California, Orr 2503 (1969); 3181, isolated from type strain CMI 86177 (1969); 4589/soil/Spain, Guarro, Faculty of Medicine, Univ. of Barcelona FFBA 216 (1982).

*Arthroderma uncinatum* Dawson and Gentles, 1961 Sabouraudia **1**:55 FIG 1a-g.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** (soil, Scotland).

**Anamorph name:** *Trichophyton ajelloi* (Vanbreuseghem) Ajello, 1968.

**Ascomata:** pale buff, 300-900*um* diam. **Ascospores:** 1.0-1.8 x 2.5-3.2*um*. **Asci:** 5.0-6.5 x 5.4-7.2*um*. **Peridial hyphae:** hyaline to pale yellow, uncinately branched to the outside of the main hypha; cells 4.0-7.0 x 7.0-11*um*, strongly echinulate. **Appendages:** septate, smooth-walled helices, terminal, variable; occasional smooth-walled, multiseptate, fusiform macroconidia are produced by peridial hyphae. **Anamorph:** Microconidia present in some strains; pyriform to obovoid, 2.0-5.0 x 3.0-9.0*um*. Macroconidia abundant, cylindric, fusiform, 8-12 septate, thick-walled, smooth, 8.0-12 x, 18-60*um*. **In culture:** [UAMH 2759]. CER 7/25°C centre yellow, margin broad and white; reverse yellow. DSA

42/25°C yellowish cream, localized; reverse uncolored. PYE 7/25°C cream to orange-tan, powdery; reverse uncolored. (Pigmented forms can be vinaceous-red or bluish black.)

**Notes:** Widespread soil inhabitant. Recovered from soil, Belgium (Ajello *et al.*, 1965). hair of wild rats, horse lesion. Domsch, Gams and Anderson (1980) list bird nests, hair and skin scrapings as sources. Rippon (1974) reports it from cattle, dogs and squirrels. Rare pathogen of humans.In culture, formation of sexual structures is inhibited at temperatures above 25°C. No growth at 37°C.

**Material examined: UAMH** 557/soil/Alberta, coll. Carmichael (1956); 739, 740/soil/Alberta, coll. Carmichael (1960); 750/sheep wool/Alberta, coll. Carmichael (1960); 1315/soil/Alberta, coll. Carmichael, 18-8-a (1962); 2759/soil/Alberta, coll. Carmichael (1967).

*Arthroderma vanbreuseghemii* Takashio, 1973 Ann. Soc. Belge. Med. Trop. **53**:547-548 FIG 77-83, 86.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CBS** RV 27960 X 27961. (testor strains, origin undetermined).

**Anamorph name:** *Trichophyton mentagrophytes* (Robin) Blanchard, 1896. (see Rebell and Taplin (1970))

**Ascomata:** straw or buff-colored, 300-650*um* diam. **Ascospores:** 1.5-1.8 x 2.5-2.8*um*. **Asci:** 3.6-6.0 x 4.2-7.2*um*. **Peridial hyphae:** hyaline to buff, dichotomously branched; cells asymmetrically constricted, echinulate, 4.5-5.2 x 8.0-12*um*. **Appendages:** elongate, smooth-walled hyphae tapering at the apex, 60-200*um* long; and smooth-walled, helical hyphae with up to 15 gyres. **Anamorph:** Microconidia clavate or spherical, or lateral (forming clusters). Macroconidia clavate, 3-5-septate, smooth-walled, 6.0-8.0 x 20-50*um*; rare, or in "granular forms" numerous. (Morphological variation in this anamorph has engendered numerous descriptions of distinctive varieties under many species names. These are listed in Padhye and Carmichael, 1971 and Howard, 1983.) **In culture:** [UAMH 3740]. CER 14/25°C pale yellow-buff, granular; reverse yellowish to uncolored. DSA 42/25°C pinkish buff, sparse scattered. PYE 14/25°C pinkish buff, dense granular, margin irregular; reverse reddish tan to

reddish brown.

**Notes:** This species distinguished from *Arthroderma benhamiae* by mating reactions. The latter species also has slightly smaller ascospores.

**Material examined: UAMH** 3740/human/France, Badillet and Rivalier, from ATCC 24956, =RV 27435.

**CTENOMYCES** Eidam, 1880

in Cohn, Beit. Biol. Pfl. **3**:274.

**Type species:** *Ctenomyces serratus* Eidam em. Benjamin

**Ascomata:** orange-brown, globose, 100-350*u*m diam. excl. appendages. **Ascospores:** pale orange, oblate-lenticular (one side flattened), smooth, 2.0-2.6 x 3.3-3.6*u*m. **Asci:** hyaline, ±globose, 8-spored, <7*u*m, evanescent. **Peridial hyphae:** pale orange, membranous inner layer of thin-walled, hyphae; outer layer of orange-brown, septate, thick-walled, echinulate to asperulate hyphae which form a reticuloperidium. **Appendages:** pale orange-brown, septate, thick-walled, asperulate, recurved, tooth-like protuberances lining one side. **Thallism:** heterothallic. **Anamorph:** *Chrysosporium*.

**Notes:** First described as a resting or sclerotial phase of *Arthroderma curreyi* by Eidam, 1880. Benjamin (1956) clarified the identity of the two taxa.

**References:** Benjamin, 1956 (Taxonomy with respect to *Arthroderma*); Frey and Griffin, 1961 (Anamorph); Orr and Kuehn, 1963 (Review of genus and list of excluded species); Varsavsky and Reca, 1964 (Sexuality); Sekhon and Padhye, 1976.

*Ctenomyces serratus* Eidam, 1880 Cohn, Beit. Biol. Pfl. **3**:274, 1880 PL XII fig. 2. em Benjamin El Aliso **3**:307-311, 1956 PL V.

fig. 4.3, PL 4.1b,d

**Type material:** NEOTYPE *(cultura desiccata)* **CMI** 86199 (soil, Australia) *fide* Durie and Frey (1962).

**Anamorph name:** *Chrysosporium* state of *Ctenomyces serratus*.

=*Myceliophthora* state of *Ctenomyces serratus fide* van Oorschot, 1980.

**Ascomata:** orange-brown, 100-350*u*m diam. **Ascospores:** pale orange,

lenticular, asymmetrical, flattened on one side, 2.0-2.6 x 3.3-3.6*u*m. **Asci:** 4.0-6.0 x 5.0-6.0*u*m. **Peridial hyphae:** membranous inner layer of pale orange, thin-walled, densely interwoven, hyphae, 3.3-6.0*u*m diam. surrounded by orange-brown, thick-walled hyphae (Inner layer forms a cleistoperidium; outer layer forms a reticuloperidium). **Appendages:** ctenoid, 100-150*u*m long, 5-11 cells, asperulate, hooked, 26-38*u*m in length. **Anamorph:** Conidia hyaline to buff in mass, obovoid to globose, verrucose, 7.0-9.0 x 10-17*u*m (resembles *Chrysosporium asperatum fide* Domsch, Gams and Anderson (1980). **In culture:** [UAMH 1588]. CER 21/25°C yellow with white margin, slightly radiately fibrillose; reverse pale yellow with darker yellow spots. DSA 62/25°C pale, scant, feathery; reverse uncolored. PYE 21/25°C tan-colored, margin white; reverse dark reddish brown, margin pale yellow.

**Notes:** World-wide distribution. Strong predilection for feathers; also found on dung and in soil. Soil, Easter Island (Ajello and Alpert, 1972), New Guinea (Durie and Frey, 1962), Galapagos (Ajello and Padhye, 1964). Grin and Ozegovic (1963) and Pugh (1974) consider the taxon a soil saprophyte. Not pathogenic to guinea pigs under experimental conditions (Frey and Griffin, 1961).

**Material examined: UAMH** (soil isolates of *Chrysosporium* state of *Ctenomyces serratus*). 1115, 1116/California, G. F. Orr (1961); 1570/Australia, Griffin (1963); 1588/England, Dickinson (1963); 1958/India, Rhandwa '62 (=Orr SL 466) (1964); 1959/England, Dickinson (O-3012) (1964); 1960/India, Randhawa (=Orr SL85) (1964); 1961/Argentina, M. Reca (1964); 1968/sand dunes/England, Pugh '61 (=Orr 3019) (1964); 2830/India, Padhye (1967); 3197/England, Dawson, CMI 89563 (1969); 3622/Argentina, Varsavsky, (O-2) (1973); 4429/India, Jain, Dept. of Botany, Saugar CP-19 (1981). **FH** Thaxter 166 (also in TRTC)/feathers/Cuba (1903-4); Thaxter 173 (also in TRTC)/feathers/Massachusetts [cultured feathers]; Thaxter 175 (also in TRTC)/feathers/Panama [cultured feathers] (1916); Thaxter, 188/feathers/Panama [cultured feathers]; Thaxter 217/dung culture/Massachusetts; Thaxter 312/Ass dung/Russia [cultured dung].

**NANNIZZIA** Stockdale, 1961

Sabouraudia **1**:45-46 PL 1a-e.

**Type species:** *Nannizzia incurvata* Stockdale *op. cit.*

**Ascomata:** pale buff to yellowish buff, 350-500 diam.*u*m. **Ascospores:** hyaline, yellow in mass, oblate, smooth-walled, 1.5-2.0 x 2.8-3.5*u*m. **Asci:** hyaline, globose, subglobose, ovoid, 8-spored, usually <7*u*m, evanescent. **Peridial hyphae:** hyaline, septate verticillately branched hyphae; component cells elongate ossiform, moderately thick-walled, densely asperulate, ±symmetrically constricted. **Appendages:** of two types: 1. elongate, slender, smooth-walled, septate, occasionally branching, straight or loosely coiled hyphae; 2. elongate, slender, smooth-walled, septate, occasionally branching, tightly coiled hyphae. **Anamorph:** *Microsporum*; (*Chrysosporium* in one doubtful taxon).

**References:** Domsch, Gams and Anderson (1980) (Key to some of the species); Padhye *et al.*, 1973 (Culture); Padhye and Carmichael, 1972 (SEM of ascospores); Rebell and Taplin, 1970 (Identification manual for dermatophytes); Weitzman *et al.*, 1970 (Chromosome numbers).

*Nannizzia borellii* Padhye and Ajello, 1975 Mycologia **67**:1112 FIG 1-6.

**Type material:** HOLOTYPE *(cultura desiccata)* **CDC** B-2093. (hair of spiny rat, Brazil).

**Anamorph name:** *Microsporum amazonicum* Moraes, Borelli and Feo, 1967.

**Ascomata:** dull white or pale yellow, 300-500*u*m. **Ascospores:** 2.0-2.5 x 2.0-3.0*u*m. **Asci:** 4.0-5.0*u*m. **Peridial hyphae:** hyaline, dichotomously branched; cells finely echinulate. **Appendages:** elongate, septate, smooth-walled, tapering hyphae to 150*u*m long, 2.0-3.0*u*m diam. at base and 1.2-1.5*u*m at tip; elongate, smooth-walled, slender helices. **Anamorph:** Microconidia clavate, 1.6-2.3 x 4.5-6.0*u*m. Macroconidia symmetrical, spindle-shaped, echinulate to bristly, thick-walled, 1-4-septate, 10-15 x 25-37*u*m. **In culture:** [UAMH 3752]. CER 14/25°C olive-brown, scattered knot-like growths; reverse uncolored to very pale yellow. DSA 42/25°C scattered knots of dark olive-brown mycelium; reverse uncolored. PYE 14/25°C olive-brown, velvety, radiately grooved; reverse pale yellow.

**Notes:** isolated from hair of spiny rat *Proechimys guyannensis* and from a rat in genus *Oryzymys*. Probably saprophytic according to Howard, 1983.

**Material examined: UAMH** 3752 -SAC from CDC Y-82 derived from type (1974).

*Nannizzia cajetana* Ajello, 1961 Sabouraudia **1**:175 FIG 1a-f, 2a-d.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CDC** ???? (soil, Kentucky).

**Anamorph name:** *Microsporum cookei* Ajello, 1959.

**Ascomata:** pale yellow, 390-690*um* diam. **Ascospores:** golden in mass, 1.8 x 3.0-3.6*um*. **Asci:** 6.0-9.0*um* diam. **Peridial hyphae:** hyaline, verticillately branched; cells echinulate, slightly constricted at septa. **Appendages:** straight, tapered hyphae, to 480*um* long, 2.4*um* wide at base. 1.2*um* at tip; elongate, smooth-walled hyphal coils **Anamorph:** Microconidia borne singly, clavate, 2.0 x 3.0-8.0*um*. Macroconidia numerous, ellipsoidal, multiseptate, walls to 5*um* thick, echinulate, 10-15 x 31-75*um*. **In culture:** [UAMH 2937]. CER 14/25°C tan to yellow, granular, radiately grooved, margin pale violet; reverse uncolored. DSA 42/25°C bright rose-pink, localized, feathery appressed growth; reverse bright rose. PYE 42/25°C tan to violet, suede-like to slightly granular; reverse dark violet.

**Notes:** Widely distributed; isolated from soil, and hair of wild animals.

**Material examined: UAMH** 746/sheep wool/Alberta, coll. Carmichael (1960); 2937 (=ATCC 14387, +SAC from type) (1968); 3282/rat/India, Ajello CDC B-359 (1969); 3283/cotton rat/Georgia, Ajello CDC X-36 (1969); 3284/rat/Australia, Ajello CDC X-256 (1969); 3285/soil/Poland, Ajello CDC X-301 (1969).

*Nannizzia cookiella* De Clerq, 1983 Mycotaxon **18**:24-26 FIG 1-4.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CBS** (SA8mt- x SA9mt+) (soil, Ivory Coast).

**Anamorph name:** *Microsporum* state of *Nannizzia cookiella*.

**Ascomata:** pale buff to yellow, 400-800*um*. **Ascospores:** 2.0-3.0*um*. **Asci:** 4.0 x 4.0-6.0*um*. **Peridial hyphae:** pale buff, branched, distal branches curved in "running legs;" cells asperulate, 2.0-5.0 x 10-20*um*. **Appendages:** slender,

smooth-walled, approximately 2*um* wide and 64-400*um* in length, or helices 10-14*um* diam. **Anamorph:** Microconidia numerous, pyriform to elongate, 1.0-2.0 x 2.0-8.0*um*. Macroconidia numerous, ovoid, mostly 3-septate, thick-walled (2.0-4.0*um*), densely verruculose, 16-18 x 18-34*um*.

**Notes:** Colonial morphology similar to *Microsporum cookei* but macroconidia smaller. No growth at 37°C, apparently non-pathogenic.

**Material examined:** None. Description taken from the original.

*Nannizzia corniculata* Takashio and C. DeVroey, 1982 Mycotaxon **14**:383-389 FIG 1-6.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CBS** (SA3 x SA26) (soil, Somalia).

**Anamorph name:** *Microsporum boullardii* Dominik and Majchrowicj, 1966.

**Ascomata:** pale buff to yellow-buff, 370-870*um* diam. **Ascospores:** 1.7 x 2.7*um*. **Asci:** 4.0-5.0 x 5.0-5.5*um*. **Peridial hyphae:** pale buff, verticillately branched (up to 4x) at distal ends. **Appendages:** straight or curved, elongate, slender, smooth-walled, 2-2.5 up to 11 times coiled, coils 10-20*um* wide; distal branches 1-5 celled, curved or coiled; ossiform cells 3.0-7.0 x 10-28*um*, moderately thick-walled, densely asperulate, termini thickened, except terminal cells which taper slightly to a blunt end. **Anamorph:** Microconidia 1.7-2.9 x 3.3-8.3*um*. Macroconidia 1-8-septate, (usually 4-septate), 4.6-9.0 x 23-54*um*.

**Notes:** Known only from the type isolations.

**Material examined:** None. Description taken from the original.

*Nannizzia fulva* Stockdale, 1964 Sabouraudia **3**:120 FIG 1ef, PL 1ef.

**Type material:** HOLOTYPE *(cultura desiccata)* . **CMI** 100665 (soil, Hungary).

=*Nannizzia gypsea* var. *fulva* (Stockdale) Apinis, 1964.

**Anamorph name:** *Microsporum fulvum* Uriburu, 1909. (see Rebell and Taplin (1970))

**Ascomata:** pale buff to yellow-buff, 350-1250*um* diam. **Ascospores:** 1.5-2.0 x 2.8-3.5*um*. **Asci:** 5.0-7.0*um*. **Peridial hyphae:** pale buff, verticillately branched with up to 5 branches curving in to main axis; cells with 1-3 ±symmetrical constrictions, up to 7-8*um* diam., densely asperulate. **Appendages:** arising

terminally and laterally from cells of peridial hyphae: straight, slender, smooth-walled, septate hyphae, up to 250*um* long, 3-4.5*um* wide at base tapering to 1.5-2*um* wide at tip; slender, smooth-walled, septate, helical hyphae, ±branched, loosely to tightly coiled. **Anamorph:** Microconidia clavate, smooth-walled or slightly roughened, unicellular or sometimes 1-septate, sessile or on short sterigmata, 1.7-3.3 x 3.3-8.3*um*. Macroconidia cylindrical, slightly tapering towards each end and with a rounded apex, or clavate, occasionally ellipsoid or fusiform, up to 5-septate, walls thick (0.8-1.1*um*) and verrucose, 7.5-12 x 25-58*um*. **In culture:** [UAMH 1480]. CER 21/25°C creamy buff, slightly granular to felty; reverse cream-yellow. DSA 14/25°C white, sparse and very localized; reverse uncolored. PYE 35/25°C tawny to rosy buff, surface irregular and chamois like; reverse cream-yellow.

**Notes:** World-wide in distribution. Occasionally pathogenic.

**Material examined: UAMH** 1480 -SAC from CMI 86180 (Szathmary) (1962).

*Nannizzia grubyia* Georg, Ajello, Friedman and Brinkman, 1962 Sabouraudia 1:194 PL 2 and 3.

**Type material:** HOLOTYPE (*cultura desiccata*) **ATCC** 14422(+) x 14423(-) (SACs from fertile cross between isolates from a dog and a human).

**Anamorph name:** *Microsporum vanbreuseghmii* Georg *et al.*, 1962.

**Ascomata:** white at first, buff at maturity, 150-600*um* diam. **Ascospores:** 2.4 x 3.0*um*. **Asci:** 4.8-6.0*um*. **Peridial hyphae:** hyaline, uncinately and dichotomously branched; cells thick-walled, moderately constricted in centre, 4-5*um* diam. (occasionally 7.5-10 *um* diam.) densely echinulate. **Appendages:** short, smooth-walled, loosely coiled hyphae with 2-3 gyres and elongate, smooth-walled septate hyphae (1.5-3*um* diam.) with up to 50 gyres. **Anamorph:** Microconidia numerous, single and lateral, pyriform to obovoid, 4.0 x 9.0*um*. Macroconidia numerous, stalked, lateral or terminal, cylindro-fusiform with thick (2-2.5*um*), echinulate walls, mostly 7-10 septate, 10-11 x 59-62*um*. **In culture:** [UAMH 1465]. CER 21/25°C rosy pink, granular; reverse pale yellow with slight pink tinge. PYE 14/25°C bright rosy pink, felt like; reverse pale yellow.

**Notes:** Cosmopolitan. Not a significant pathogen but may cause disease in

opossums, squirrels or dogs, and is pathogenic to guinea pigs under experimental conditions Domsch, Gams and Anderson (1980). **UAMH** 1465 from CDC Georg X470 (1965).

*Nannizzia gypsea* (Nannizzi) Stockdale, 1963 Sabouraudia **3**:119, FIG 1cd, PL 1cd.

**Type material:** NEOTYPE *(cultura desiccata)* **CMI** 80558 (soil, Australia) *fide* Stockdale *op. cit.*

≡*Gymnoascus gypseus* Nannizzi, 1927. (Basionym).

≡*Nannizzia gypsea* var. *gypsea* (Stockdale) Apinis, 1964.

**Anamorph name:** *Microsporum gypseum* (Bodin) Guiart and Grigorakis *sensu lato* (see Rebell and Taplin (1970))

**Ascomata:** pale buff, 300-750(950)*um* diam. **Ascospores:** 1.5-2.0 x 2.5-4.0*um*. **Asci:** 5.0-7.0*um*. **Peridial hyphae:** hyaline, up to 4 divergent, verticillate branches, cells densely verrucose, with 1-3 symmetrical constrictions, 4.0-7.0 x 8.0-20*um*. **Appendages:** terminal; straight, slender, smooth-walled, septate, up to 250*um* long, 2.5-4.0*um* wide at base, tapering to 1.5-2.0 at tip; helices, 2.5-3.5*um* wide at base, tapering to 1.5-2.0*um*, loosely to tightly coiled. **Anamorph:** Microconidia clavate, smooth-walled or slightly roughened, 1.7-3.3 x 3.5-8.5*um*, hyaline chlamydospores rare. Macroconidia moderately thick-walled (0.8-1.2*um*), verrucose, ellipsoid to fusiform, up to 5-septate, 8.5-15 x 25-58*um* often with a "whip-like" appendage, to 1.0-1.5 x 30*um*, on repeatedly branched conidiophores. **In culture:** [UAMH 1485]. CER 21/25°C tawny buff, granular; reverse uncolored. PYE 35/25°C tawny buff with patches of fine white overgrowth; reverse yellowish brown, pink to rosy vinaceous at centre.

**Notes:** Probably cosmopolitan. The anamorph is frequently recovered from soil, hair and skin of monkeys, dogs, rats, mice and other small mammals. Ajello (1953) provides detailed discussion of the anamorph, and Weitzman (1964) a genetic study of pleomorphism.

**Material examined: UAMH** 1485 +SAC from CMI 86175, Dawson (1962); 1616/soil/Oklahoma, Keeping #3 (1963); 3342/child/Michigan, Hand, CDC X-11

(1970); 3344/norway rat/Georgia, Menges 2655 =CDC X-42 (1970); 3345/dog/Georgia, Menges NC 13 =CDC X-41 (1970); 3346/field mouse/Georgia, Menges 2600 =CDC X-42 (1970); 3350/eye lesion/South Carolina, Georg CDC X-531 (1970).

*Nannizzia incurvata* Stockdale, 1961 Sabouraudia **1**:46-47 PL 1a-e.

FIG 4.4

**Type material:** HOLOTYPE *(cultura desiccata)* . **CMI** 82777 (human skin lesions, England).

=*Nannizzia gypsea* var. *incurvata* (Stockdale) Apinis, 1964.

**Anamorph name:** *Microsporum gypseum* (Bodin) Guiart and Grigorakis *sensu lato*. (see Rebell and Taplin (1970))

**Ascomata:** white becoming yellowish buff, 350-500*u*m diam. **Ascospores:** 1.5-2.0 x 2.5-3.6*u*m. **Asci:** 5.0-7.0*u*m. **Peridial hyphae:** up to 5, often convergent, verticillate branches, curving toward main axis; cells 7.0-8.0*u*m diam. and 10-24*u*m long with ±symmetrical constrictions, densely asperulate. **Appendages:** elongate, slender, smooth-walled, septate, occasionally branched, up to 300*u*m long and 3.0-4.5*u*m wide at base tapering to 1.5-2.0*u*m, straightor with up to 30 coils. **Anamorph:** Microconidia clavate, smooth-walled or slightly roughened, 1.7-3.3 x 3.5-8.5*u*m, hyaline chlamydospores rare. Macroconidia moderately thick-walled (0.8-1.2*u*m), verrucose, ellipsoid to fusiform, up to 5-septate, 8.5-15 x 25-58*u*m, on repeatedly branched conidiophores. **In culture:** [UAMH 1484]. CER 14/25°C pale yellowish white, radiate; reverse pale yellow. PYE 14/25°C yellowish buff, felty, concentrically grooved; reverse orange-brown to tan.

**Notes:** Kwon-Chung (1969) gives a developmental study of this species. Varsavsky *et al*. (1966) report a mutant with smooth-walled conidia. Weitzman (1964) provides a genetic study of pleomorphism. Recorded from Germany, Czechoslovakia, Netherlands, Iran from birds and field mice (Domsch, Gams and Anderson (1980)).

**Material examined: UAMH** 1484 =CMI 82777 from C. H. Whittle, (type as cited) (1962).

*Nannizzia obtusa* Dawson and Gentles, 1961 Sabouraudia **1**:56-57 PL 4a-e.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** (pig, Kenya and human, Cuba).

**Anamorph name:** *Microsporum nanum* Fuentes, 1956. (see Rebell and Taplin (1970))

**Ascomata:** pale buff, 250-450*u*m diam. **Ascospores:** 1.2-2.0 x 2.7-3.2*u*m. **Asci:** 5.0-6.0 x 5.5-6.5*u*m. **Peridial hyphae:** pale yellow, branching dichotomous or occasionally verticillate with angle obtuse; cells 4.0-7.0 x 8.0-20.0*u*m with 1 or 2 slight constrictions, echinulate. **Appendages:** lateral or terminal, septate, smooth-walled, tightly coiled; and/or terminal, elongate, slender, septate, to 450*u*m long. **Anamorph:** Microconidia sessile, clavate to cylindrical, mostly 2.0 x 5.0*u*m. Macroconidia numerous, thick-walled, finely verrucose, ovoid or ellipsoidal (rarely spherical), 5.0-7.0 x 17-18*u*m (rarely 24*u*m long and more than 3-celled). **In culture:** [UAMH 3498]. CER 21/25°C ochre to yellow, granular with a broad hyaline margin; reverse yellowish tan. DSA 42/25°C yellowish tan, sparse growth; reverse tan to yellow. PYE 21/25°C ochre yellow with cream overgrowth, cottony with irregular hummocks; reverse reddish brown at the centre, margin yellowish tan.

**Notes:** Cosmopolitan pathogen of pigs, also occasionally of man.

**Material examined: UAMH** 592/human skin lesion/Alberta, coll. Carmichael (1957); 1128/human/Mexico, Georg CDC X-427 (1961); 1129/human/Louisiana, Georg CDC X-310 (1961); 1130/human/Indiana, Georg X-313 (1961); 3498/human/Alberta, coll. Carmichael (1972); 4133/pig/Alberta, Vet. Lab. Lethbridge 911 (1978).

*Nannizzia ossicola* (Rostrup) Apinis, 1964 Mycol. Pap. **96**:33-34.

**Type material:** HOLOTYPE (bones, feathers) **Royal Veterinary and Agricultural College, Copenhagen** (dead seabirds, Britain).

=*Gymnoascus ossicola* Rostrup, Bot. Tidssk. 21:45, 1897 (Basionym).

=*Rollandina ossicola* (Rostrup) Apinis, Trans. Brit. mycol. Soc. **55**:500 1970.

**Anamorph name:** *Chrysosporium* ? (similar to *Chrysosporium tropicum* Carmichael, *fide* Apinis *op. cit.*).

**Ascomata:** white (grey or yellowish with age), 2-5mm diam. appearing smooth and firm at maturity. **Ascospores:** hyaline, very slightly roughened, 1.0-1.5 x 2.0-3.5*u*m. **Asci:** 6.0-8.0*u*m. **Peridial hyphae:** hyaline, loosely interwoven branched and anastomosed hyphae, 2.0-5.0*u*m, septate, delicately asperulate. **Appendages:** numerous, relatively short, hyaline, septate, branched, delicately roughened straight, bent or coiled, rounded at tip. **Anamorph:** conidia subglobose, angular, ovoid or pyriform, spinulose, 2.5-5.0 x 5.0-9.0*u*m.

**Notes:** No cultures available. Material on bones and feathers of dead seabirds at Skegness Coast, Great Britain at Royal Veterinary and Agricultural College, Copenhagen, 1954 was examined by Apinis and checked against original description. He later moved the species to *Rollandina* (a rejected name). This species is not well accommodated in *Nannizzia* due to the size and texture of the ascomata, and the nature of the anamorph. The roughened ascospores might indicate that this is a species of *Nannizziopsis* of the Onygenaceae. Further clarification of the taxon requires fresh material.

*Nannizzia otae* Hasegawa and Usui, 1974 Jap. J. Vet. Sci. **36**:447-449 FIG 1-6.

**Type material:** HOLOTYPE *(cultura desiccata)* . **VMUT** -1 74037(+) X 74039(-) (cat, Japan).

**Anamorph name:** *Microsporum canis* Bodin, 1902. (see Rebell and Taplin (1970))

**Ascomata:** white to pale buff, 280-700*u*m diam. excl. appendages. **Ascospores:** 2.0-2.5 x 2.5-3.8*u*m. **Asci:** 5.0-7.0*u*m. **Peridial hyphae:** hyaline, branching dichotomous or verticillate, tips often blunt and curved toward or away from the main axis; cells constricted at septa, echinulate. **Appendages:** long, straight, slender, smooth-walled hyphae up to 150*u*m long, helical. **Anamorph:** Microconidia clavate, 2.5-3.5 x 4.0-7.0*u*m. Macroconidia spindle-shaped, thick-walled (to 4*u*m), heavily roughened with puncta and warts especially at distal end, 15-20 x 60-125*u*m, up to 14-septate, septa frequently diagonal. **In culture:** [UAMH 3754]. CER 14/25°C centre yellow, felty, radiate striate, margin broad, white, striate; reverse yellow. DSA 42/25°C cream tan,

localized knots of mycelium on hairs; reverse pale yellow. PYE 7/25°C bright yellowish tan, floccose, pin-wheel pattern with radiate streaks of darker brown; reverse reddish tan, at margin bright tan yellow.

**Notes:** Common pathogen of kittens, puppies and children. Occasionally isolated from soil (Emmons *et al.*).

**Material examined: UAMH** 3754 -SAC (=VUT 74039, mating type strain as cited), Hasegawa (1975).

*Nannizzia persicolor* Stockdale, 1967 Sabouraudia **5**:357-358 FIG 1ab.

**Type material:** HOLOTYPE *(cultura desiccata)* **CMI** 126886 (soil and human hair).

=*Nannizzia quinckeana* Balabanov and Schick, 1970 *fide* Collinge and Stockdale, 1973 and Padhye and Ajello, 1974.

**Anamorph name:** *Microsporum persicolor* (Sabouraud) Guiart and Grigorakis, 1928. (see Rebell and Taplin (1970))

**Ascomata:** buff, 350-900*u*m diam. **Ascospores:** 1.6-2.1 x 2.5-3.3*u*m. **Asci:** 4.5-6.0 x 5.0-7.0*u*m. **Peridial hyphae:** pale buff, branched; cells symmetrical with one central constriction, 3.5-7.5 x 5.5-27.5*u*m, verruculose. **Appendages:** numerous, branched helical coils. **Anamorph:** Microconidia clavate. Macroconidia minutely echinulate, rare, clavate to fusiform. **In culture:** [UAMH 2939]. CER 14/25°C yellow-tan, granular; reverse white to pale beige. DSA 42/25°C yellowish beige, granular; reverse tan. PYE 22/25°C cream-tan, suede to slightly granular; reverse tan-brown.

**Notes:** Widely distributed, mild pathogen of small rodents (bank voles and field voles); rarely infects humans (Padhye *et al.*, 1973).

**Material examined: UAMH** 2557/fork-tailed kite/Australia, Rees H. 427 (1965); 2612/soil/South Africa, SAIMR, 192 (1966); 2841/chicken feathers/India, Padhye (1967); 2939 -SAC from CMI 117064 from type (1968); 3509/human foot/Maryland, Ajello, CDC 40-72-018500 (1972); 3511/human/Quebec, Blank #1 (1972); 3514/human/Pennsylvania, Blank #12 (1972); 4023/vole/Quebec, Kapica, McGill Univ. (1977); 4024/human/Quebec, Kapica, McGill Univ. (1977); 4370/human/Edmonton, Rodvang (1981).

*Nannizzia racemosa* Rush-Munroe, Smith and Borelli, 1970 Mycologia **62**:858 FIG 1-5.

**Type material**: HOLOTYPE *(cultura desiccata)* **CMI 128984** (forest rat, Venezuela).

**Anamorph name**: *Microsporum racemosum* Borelli, 1965.

**Ascomata**: pale buff, 300-700*u*m diam. **Ascospores**: 1.2-1.5 x 2.5-3.0*u*m. **Asci**: 4.4-5.5*u*m. **Peridial hyphae**: hyaline, verticillately and dichotomously branched, (up to 4 branches per cell apex), cells, with up to 3 ±symmetrical constrictions, echinulate, to 8*u*m diam. **Appendages**: slender, smooth-walled, septate, 2.3-3.0*u*m wide at base, tapering to 1.5-2.0*u*m at the tip and with up to 15 gyres; straight, slender, smooth-walled, 3.0-4.0*u*m wide at base tapering to 1.7-2.0*u*m at tip, to 380*u*m long; delicate, "flagellum-like," smooth-walled, 0.7-0.9*u*m wide and to 200*u*m long. **Anamorph**: Microconidia clavate, stalked and borne in large racemes. Macroconidia spindle-shaped, echinulate, thick-walled, 1-5 septate, 12-15 x 55-65*u*m **In culture**: [UAMH 3367]. CER 14/25°C cream-colored, smooth; reverse violet at margin, centre yellow. DSA 42/25°C white, granular; reverse uncolored. PYE 14/25°C cream-colored, thick, smooth; reverse yellow with violet patches.

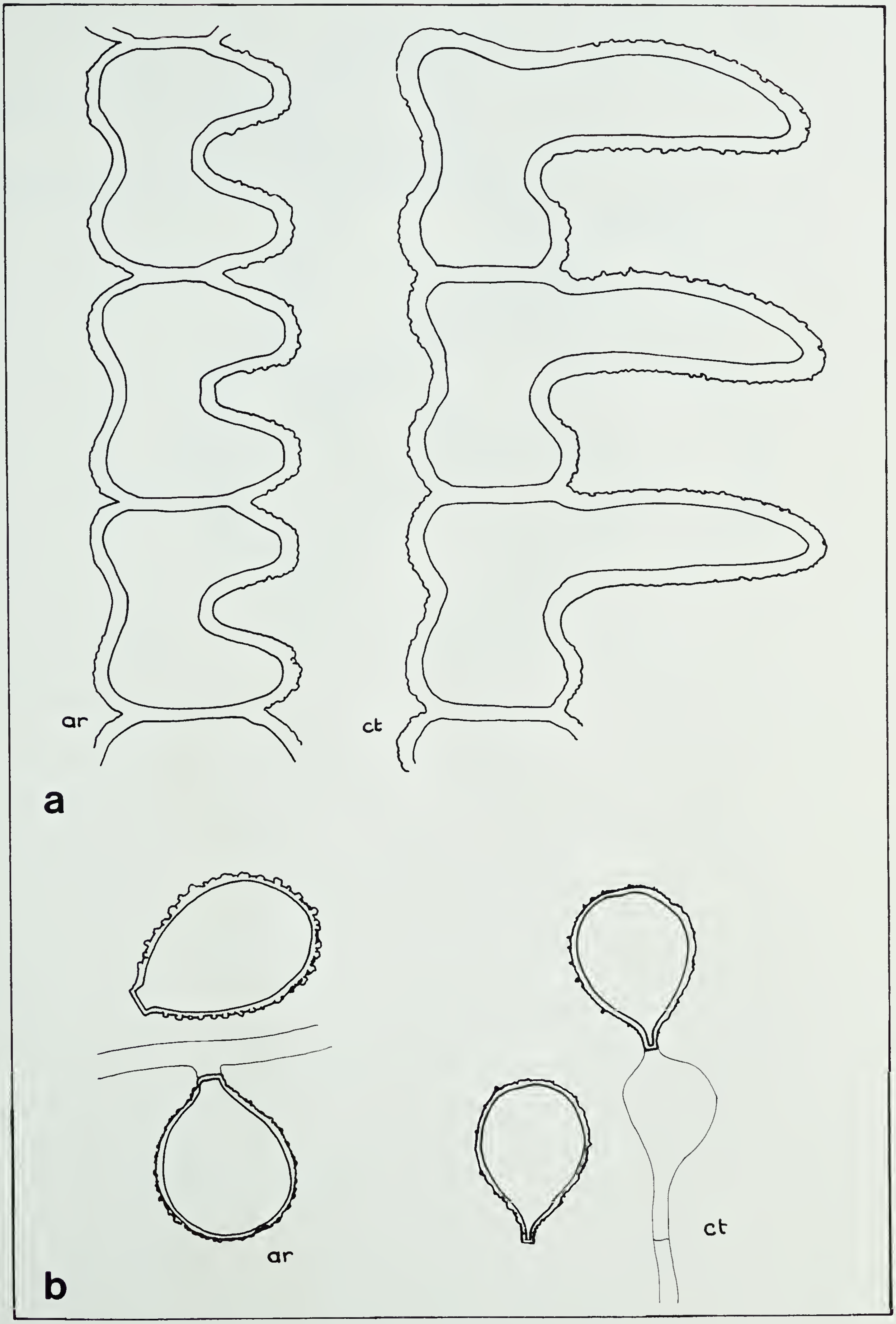
**Notes**: Probably cosmopolitan (Howard, 1983). Pathogenic under experimental conditions. Reported from forest rat, Venezuela; soil, Brazil; squirrel and badger soil, Europe (Rush-Munroe *et al.*, *op. cit.*)

**Material examined**: **UAMH** 3367 -SAC from Rush-Munroe, New Zealand.

Figure 4.1. Diagramatic comparison of similar structures in *Arthroderma* and *Ctenomyces*.

**a** Diagramatic comparison of cell morphology in a section of a peridial hypha of *Arthroderma tuberculatum* ('ar')and in a section of a ctenoid appendage of *Ctenomyces serratus* ('ct'). X2000.

**b** The conidia and conidiogenous cells of the anamorphs of *Arthroderma tuberculatum* ('ar') and *Ctenomyces serratus* ('ct'). X400.



ar
ct
a
ar
ct
b

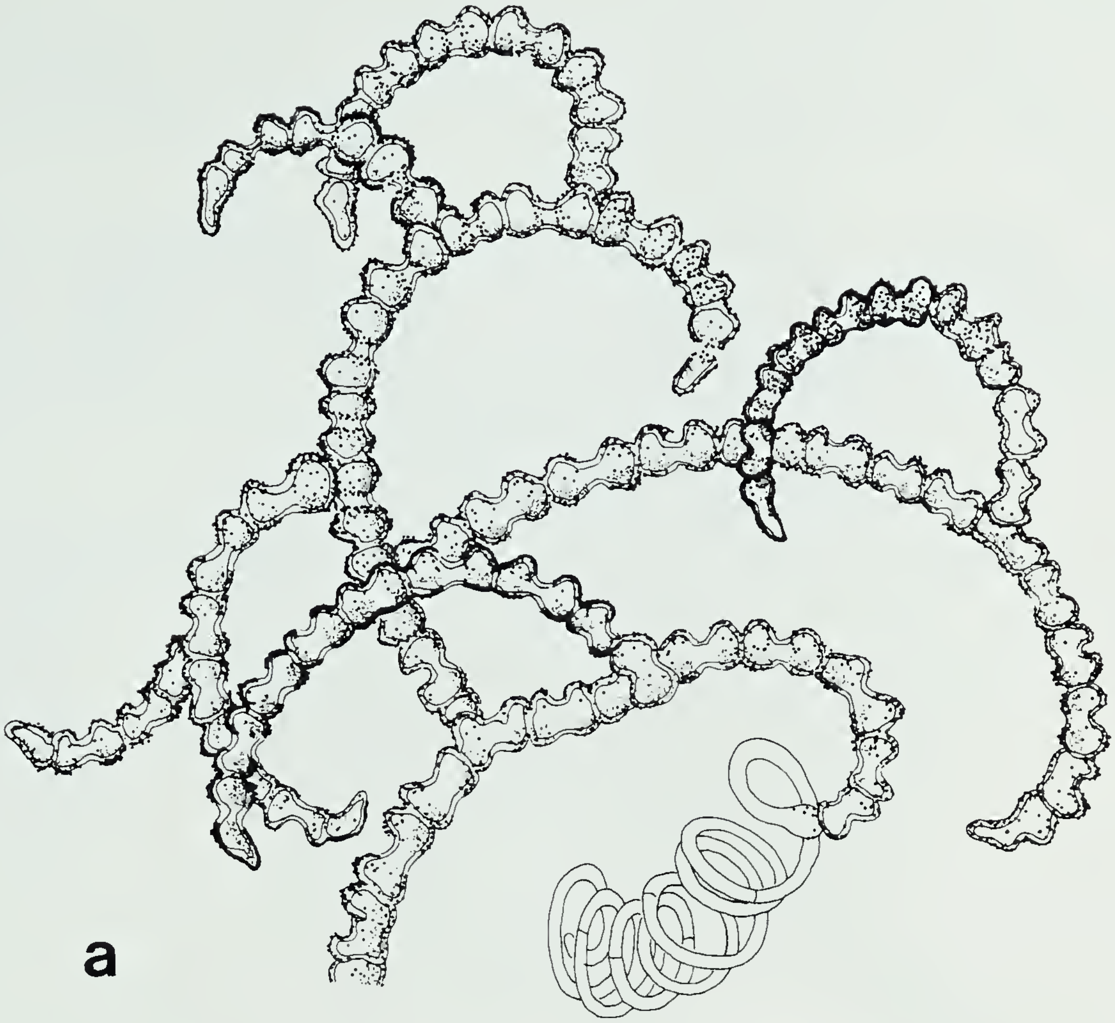
Figure 4.2. *Arthroderma quadrifidum* (UAMH 1686).

a Peridial hyphae of thick-walled, echinulate, ossiform cells.

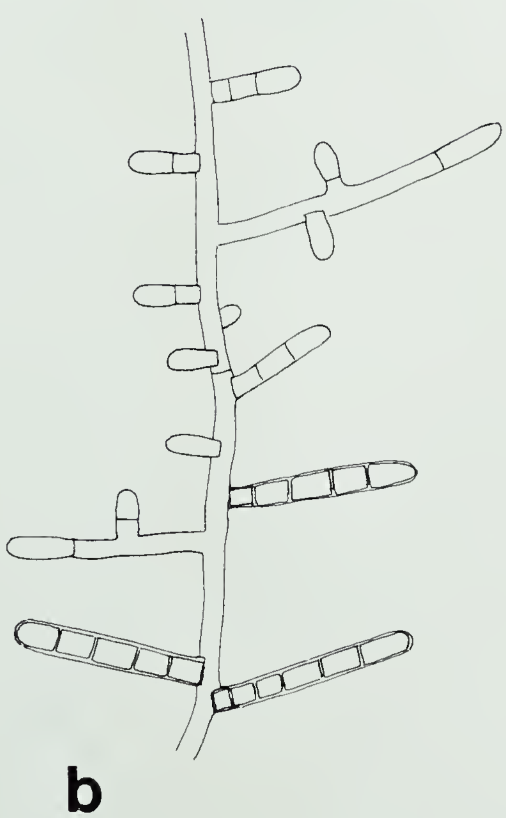
b Terminal thin-walled, smooth, septate, coiled appendage. a & b X1000.

c Ascus and individual smooth-walled ascospores. X8500.

d Anamorph *Trichophyton terrestre* s. l., with thick-walled, 0-multiseptate conidia. X1500.



a



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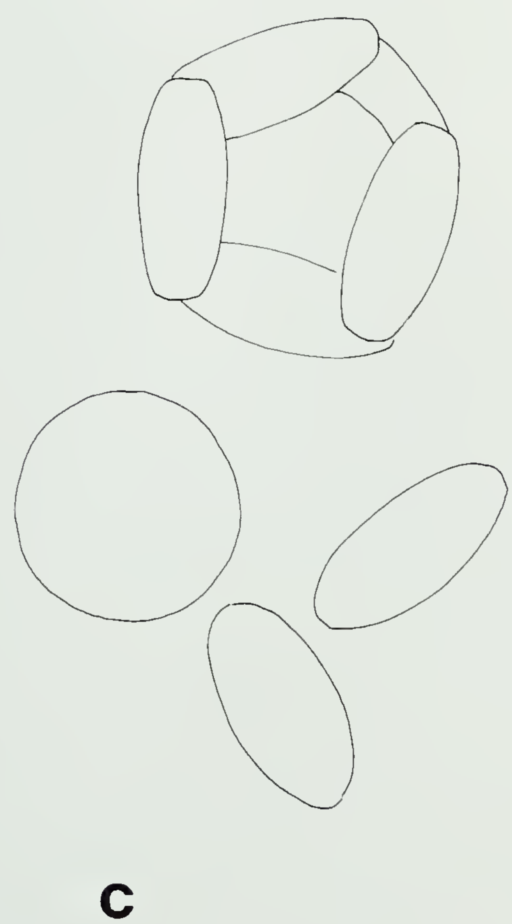


c

Figure 4.3. *Ctenomyces serratus* (TRTC Thaxter 173).

**a** Ascoma with pseudoparenchymatous inner peridium surrounded by thick-walled reticulothecial hyphae bearing roughened pectinate appendages. X250.

**b** Rough-walled conidia of anamorph, *Chrysosporium* state of *Ctenomyces serratus*; conidia borne on thin-walled, inflated, vesicular cells. X230.

**c** Smooth-walled oblate ascospores with one flattened pole. X880.

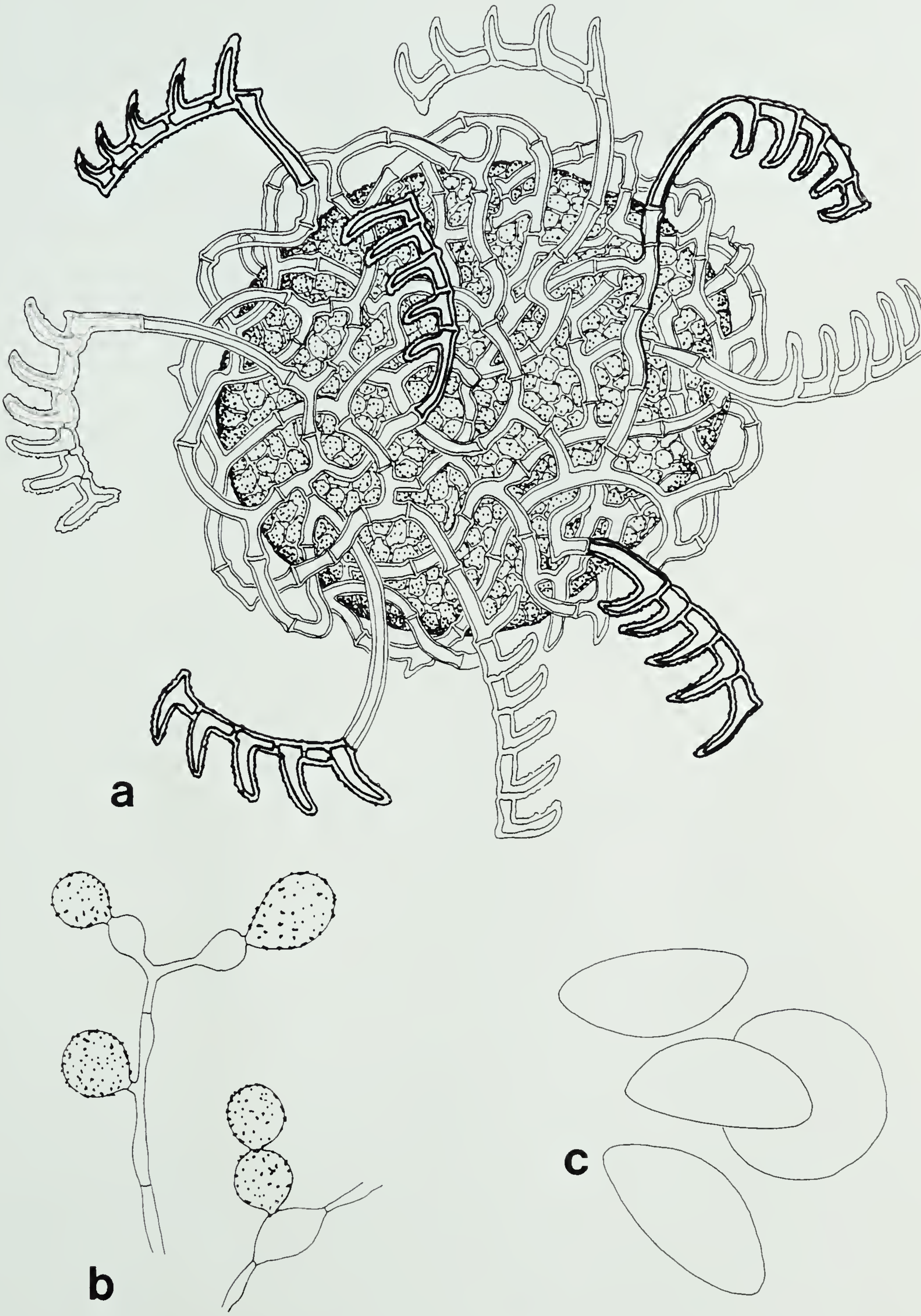

a
b
c

Figure 4.4. *Nannizzia incurvata* (UAMH 1484).

**a** Peridial hyphae of thick-walled, echinulate, ossiform cells with 1-3 slight constrictions and a thin-walled, coiled appendage. a & b X1000.

**b** Anamorph of *Microsporum gypseum*; microconidia one-celled, clavate; macroconidia roughened and septate; macroconidium on right collapsed between septa. X875.

**c** Smooth-walled oblate ascospores and ascus. X8125.

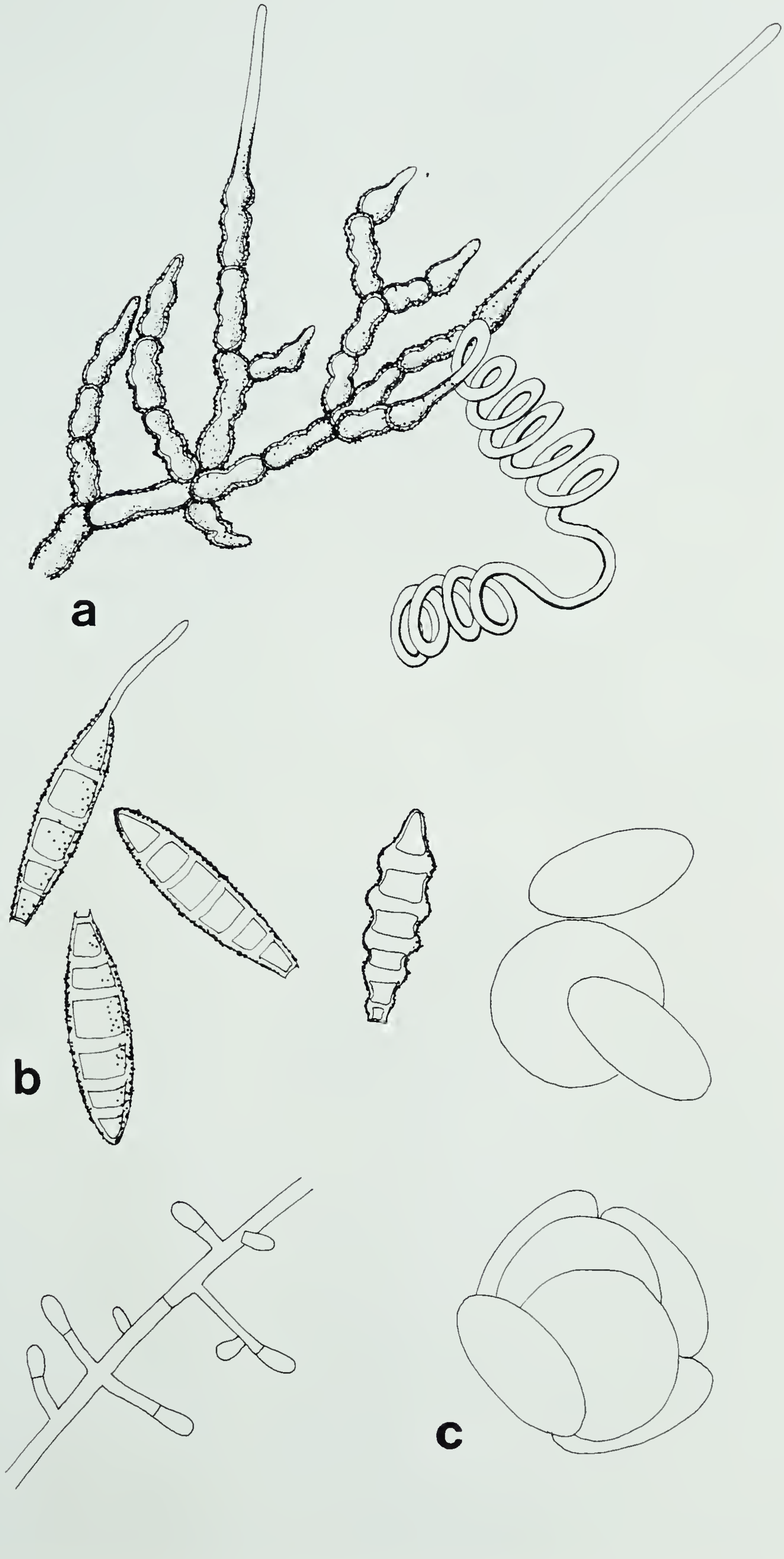

a
b
c

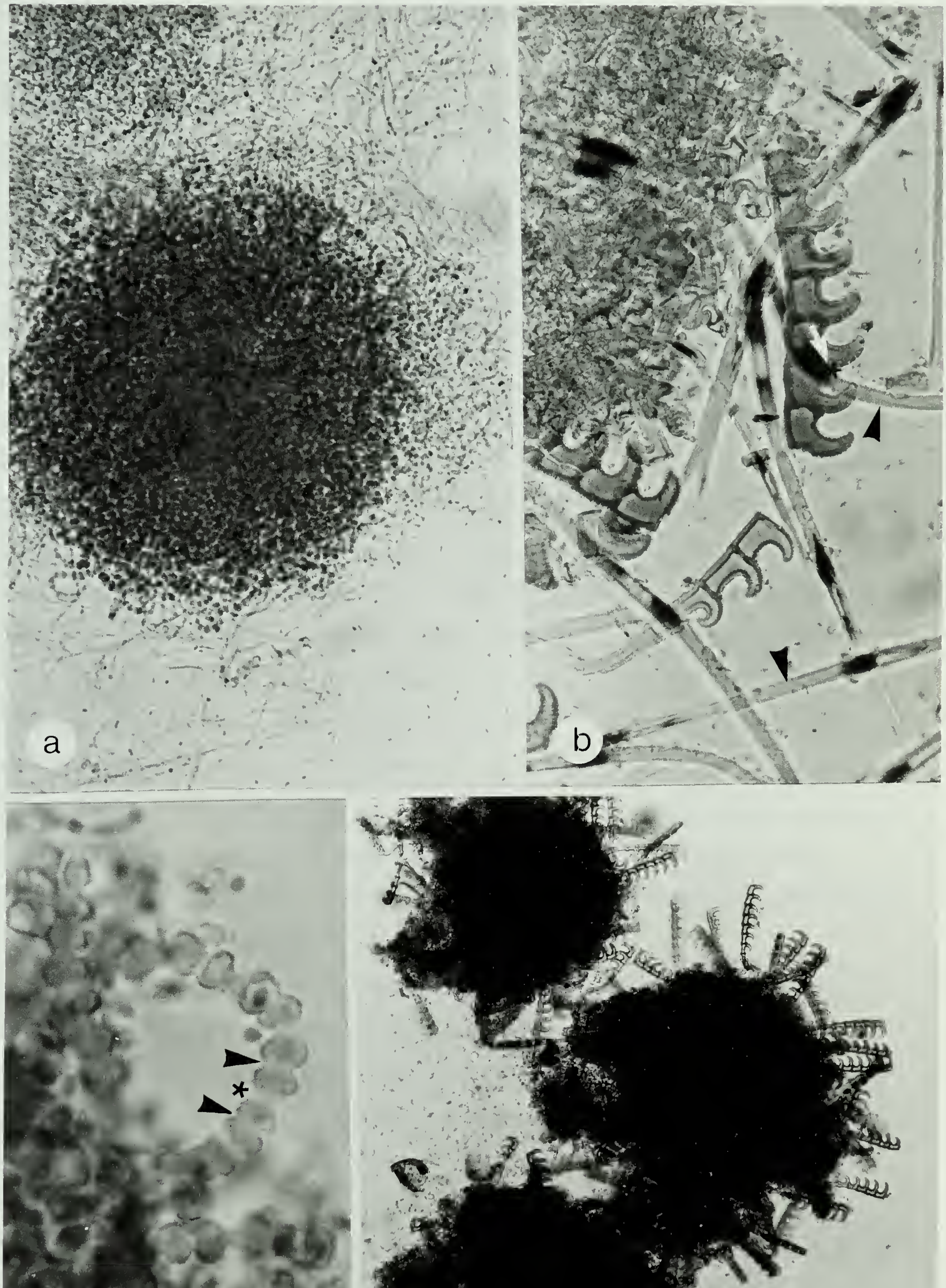
Plate 4.1

**a** *Arthroderma curreyi* (UAMH 4768). Ascoma from dung sample. Ossiform cells composing the reticuloperidium discernible at periphery. X220.

**b** *Ctenomyces serratus* (FH Thaxter 173). Arrows indicate feather pennulae. The significance of the appendage morphology indicated at asterisk. X370.

**c** Ossiform cells of the peridial hyphae of *Arthroderma curreyi* (UAMH 4768). Arrows indicate septa; asterisk indicates central constriction. X2500.

**d** *Ctenomyces serratus* (FH Thaxter 166). Three individual ascomata showing morphology and disposition of ctenoid appendages on the external hyphae. X105.


a
b
c
d

# CHAPTER 5

## GYMNOASCACEAE

Gymnoascaceae Baranetzky, 1872

**Type genus:** *Gymnoascus* Baranetzky, 1872.

**Ascomata:** white, yellow, red, green or brown, never darkly pigmented; ±globose when discrete; ascomata often confluent or barely differentiated, in this case, consisting of clusters of ascospores surrounded by vegetative mycelium; arising from one or more gametangial pairs; diameter of individual ascomata generally <1000*u*m. **Ascospores:** hyaline, pale or brightly colored - yellow, orange or red; generally oblate (never globose), thick-walled, unornamented, or with one or two equatorial rims, or with a shallow equatorial groove; polar thickenings present or absent; walls smooth or undulate (lumpy) in some taxa, never pitted; up to 9.0*u*m diam. **Asci:** globose to ovoid, to 15*u*m diam. **Peridial hyphae:** variable in three categories; hyphae undifferentiated from vegetative hyphae and/or slightly irregular, resembling, in total, a mass of cob-webs and forming a telaperidium; or disjointed, irregular, thick-walled elements lacking any distinct organization and forming an incompositothecium; or thick-walled, regular elements organized to resemble a cage-like structure or reticuloperidium; never forming a membranous peridium. **Appendages:** absent or well-differentiated and of elongate, ±branched, thick-walled hyphae with characteristic shape and/or branching pattern. **Thallism:** homothallic. **Anamorph:** absent or rare; arthroconidial.

**Notes:** The taxa included in this family represent an artificial assemblage which, by their peridial characteristics and habitat, have been traditionally classified with the keratinolytic Arthrodermataceae and Onygenaceae, and the cellulolytic Myxotrichaceae. Many Gymnoascaceae also share the same habitats as these families. The Gymnoascaceae do not display any marked substrate preferences although some may be mildly cellulolytic.

The well-developed reticuloperidium of *Gymnoascus* is superficially similar to the reticuloperidium of many Onygenaceae (*Auxarthron* in particular), as well as *Ctenomyces* of the Arthrodermataceae, and many Myxotrichaceae. The grouping of taxa with these mesh-like peridia was a logical approach to the development

of the concept of the Gymnoascaceae. Closer examination of ascospore morphology and substrate preferences indicates that groupings made purely on the basis of this one character yield an unsatisfactory and artificial system. Convergence of morphological characteristics has several precedents in the fungi (e.g. gasteromycetation and cyphellization in basidiomycetes) (Singer, 1975), and in the vascular plants (e.g. succulence and leaf-spine modifications in some Cactaceae and Euphorbiaceae). In fact, examples could be drawn from nearly all major groups of organisms.

I strongly suspect that the affinities of some of the taxa here considered in the Gymnoascaceae are closer to the Eurotiales than to the Onygenales. Some species do not have an anamorph and, since the primary distinction between the two orders is based conidium ontogeny, satisfactory disposition of these species is difficult. The genus *Talaromyces* of the Eurotiales produces a distinctive telaperidium and this genus (among others of the order) is easily confused with *Arachniotus* and *Gymnascella*. None of the Eurotiales produces a reticuloperidium, similar to that of *Gymnoascus*, although this order exhibits almost every other conceivable peridium variation (from lacking in *Byssochlamys*, to complex and subtended by a stipe in *Penicilliopsis*). I suspect that the "missing" peridial variation (i.e. reticuloperidium) in the Eurotiales might eventually be determined to be represented by *Gymnoascus*. In this case the Eurotiales and the Onygenales would prove a striking example of parallel evolution, with the reticuloperidium of *Gymnoascus* mirrored by the similar reticuloperidium of *Auxarthron* (See Table 3.2). Further, the incompositothecium of *Gymnascella devroeyi* may also be Eurotialean.

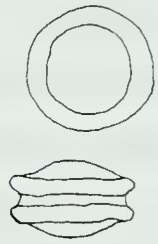
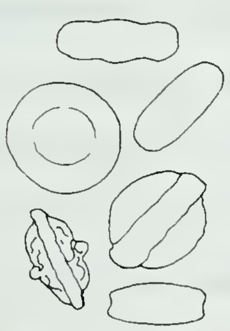
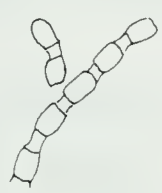
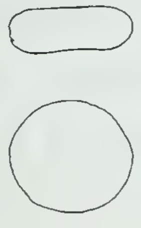
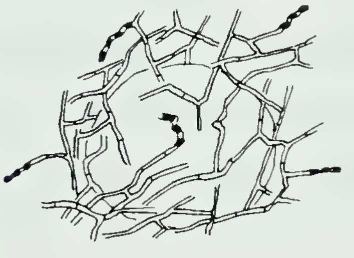
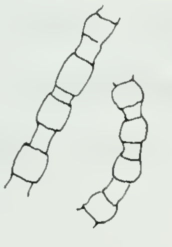
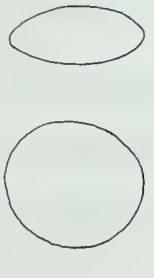
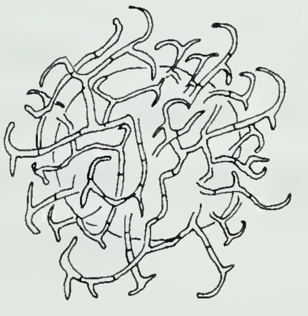
None of the Gymnoascaceae (as they are defined here) have been implicated as *bona fide* pathogens of humans or other animals, although they are frequently isolated from animal materials (dung, rejectamenda, litter and soil associated with animals), or from the animals themselves (lungs, skin scrapings, hair etc.) They are also isolated, but less often, from agricultural soils.

The frequent association of these taxa with animals might be due to an inability to compete with other fungi in other habitats. Many are slow growing even on artificial media; and on natural substrata in culture, they are usually

among the later species to develop. Ecological studies of the group are limited to brief records in substrate or habitat surveys (e.g. Dunn and Baker, 1983). A major impediment to ecological studies has been a lack of a satisfactory taxonomic treatment. This deficiency may explain why many ecological studies of probably sources of Gymnoascaceae (e.g: owl pellets, Philips and Dindal, 1982; various types of herbivore dung, Angel and Wicklow, 1983) surprisingly lack records of these taxa. Data from ecological and ultrastructural studies may give the information required to determine natural relationships among these taxa and relationships to representatives of other orders.

TABLE 5.1

GENERA OF GYMNOASCACEAE

| Genus | Ascospores | Peridia and Appendages | Anamorphs |
|---|---|---|---|
| Acitheca |  |  | ? |
| Arachniotus |  |  | —— |
| Gymnascella |  |  |  |
| Gymnoascoideus |  |  |  |
| Gymnoascus |  |  | —— |

**ACITHECA** gen. nov.

*Typus: Acitheca purpurea* Thaxter ex Currah *sp. nov.*

*Ascoma rufula fulva, globosa, 200-750um, appendiculi inclusi. Ascosporae purpurae aut violae, oblatae, levae, <6um diam., octospori. Asci globosi aut ovati, 8.0-11um diam. Hyphae peridii purpurae, crasso-parietales, asperatae, sinuosae et raro ramosae, intexerate facere theca reticulata. Appendicula sinuosa, aliquando ramosae, elongatae, acutae, modo aci. Homothallicus aut heterothallicus ignotus. Stat. conid. ignotus.*

**ACITHECA** gen. nov.

(*acus* - needle; *theca* - coat).

**Type species:** *Acitheca purpurea* Thaxter ex Currah *sp. nov.*

**Ascomata:** reddish brown, globose, 200-750*u*m diam. incl. appendages. **Ascospores:** pale purple or violet, oblate, smooth, thick-walled, 3.0-3.3 x 4.5-5.2*u*m. **Asci:** globose to ovoid, 8.0-10.4*u*m diam. **Peridial hyphae:** purple, thick-walled, slightly roughened, sinuate, branches rare, interwoven to form a reticuloperidium. **Appendages:** sinuate, occasionally branched, elongate, pointed, "needle-like." **Thallism:** unknown. **Anamorph:** unknown.

**Notes:** The well-developed reticuloperidium and smooth oblate ascospores of this taxon make it similar to *Gymnoascus*. The sinuate and sparingly septate peridial hyphae; long, tapering, aseptate, needle-like appendages; and relative lack of branching, distinguish *Acitheca* from *Gymnoascus*. In *Gymnoascus* the reticuloperidium is composed of richly branched and septate, thick-walled hyphae, and the appendages are relatively blunt. In addition, *Gymnoascus* is predominantly a coprophile and I have no records of its ever having been isolated from tree bark.

Superficially, *Acitheca* resembles *Myxotrichum cancellatum*, particularly since they both have long, needle-like appendages. However, pigmentation and most importantly, ascospore morphology are quite different. *Myxotrichum cancellatum* has dark brown peridial hyphae and long striate, pale yellow, fusoid ascospores.

The genus *Acitheca* contains only one species.

*Acitheca purpurea* Thaxter ex Currah *sp. nov.* .

*Typus ab cortice Robini, Massachusetts.*

*Ascoma rufula fulva, globosa, 200-750um diam. appendiculi inclusi. Ascosporae purpurae aut violae, oblatae, levae, crasso-parietales, 3.0-3.3 x 4.5-5.2um. Asci globosi aut ovati, 8.0-11um diam., octospori. Hyphae peridii purpurae, crasso-parietales, cum foveis minutis, sinuosa, raro ramosae. Appendicula 2.7-3.3um diam. ad origem, sinuosa, aliquando ramosae, elongatae acutae, 0.2um diam. modo promissi aci, 80-210um in longitudinem.*

*Acitheca purpurea* Thaxter ex Currah *sp. nov.*

FIG 5.1, PL 5.8a,b,c

**Type material:** HOLOTYPE (bark fragments) **FH** Thaxter 508 (*Robinia* bark, Massachusetts).

*"Gymnoascus purpureus"* Thaxter *ineditatio.*

**Ascomata:** reddish brown, globose, 200-750*u*m diam. including appendages. **Ascospores:** pale purple or violet, oblate, smooth, thick-walled, 3.0-3.3 x 4.5-5.2*u*m. **Asci:** globose to ovoid, 8.0-10.4*u*m diam. **Peridial hyphae:** purple, aseptate, thick-walled with small pits, 2.7-3.3*u*m diam., sinuate, branches rare. **Appendages:** 2.7-3.3*u*m diam. at base, sinuate, irregular, occasionally branched, evenly tapering to an acute point 0.2*u*m diam, 80-210*u*m in length. **Anamorph:** unknown. **In culture:** unknown.

**Notes:** Known only from Thaxter's type collection which consists of flakes of bark covered, for the most part, with dense patches of purple ascomata. Photographs of mounted portions of this material are presented in Plate 5.1.

**Material examined: FH** Thaxter 508 (type as cited).

**ARACHNIOTUS** Schroeter, 1893

KryptogamenFlora von Schlesiens **3**:210.

**Type species:** *Arachniotus ruber* (Van Tieghem) Schroeter *op. cit.* (LECTOTYPE *fide* Von Arx, 1970)

**Ascomata:** orange to red, discrete, spherical, 20-300*u*m, sometimes confluent. **Ascospores:** orange to yellow, smooth, "pulley-wheel" shaped with an

equatorial groove bordered by distinct ridges, poles thickened, <7.0$um$ diam. max. **Asci**: hyaline, ovoid, 10$um$ diam. approx. **Peridial hyphae**: present or absent, often sparse, smooth, thin-walled, septate, constricted at septa, sometimes irregular in diam. 1.0-3.3$um$ wide. **Anamorph**: lacking.

**Notes:** Schroeter (1893) first described *Arachniotus* to include *Gymnoascus candidus* and *Gymnoascus aureus* Eidam, 1886, and *Gymnoascus ruber* van Tieghem, 1877. He considered the genus a member of Eidam's 'Gymnoasceen' and used the nature of the peridium as a key character in distinguishing it from *Gymnoascus*, *Myxotrichum* and *Ctenomyces*. Hyaline, red or yellow ascospores distinguished *Arachniotus* from violet or brown-spored *Amauroascus*. Clements and Shear (1931) subsequently listed the type of *Arachniotus* as *Arachniotus candidus*. Unfortunately, no holotype material of this species has been found, although numerous collections are cited in Schroeter's description, including Eidam's original material on cooked rice from Breslau, Germany. In later treatments of the genus (Kuehn, 1958; Orr, Ghosh and Roy, 1977), *Arachniotus candidus* was again listed as the type of the genus. Von Arx (1970), however, listed *Arachniotus ruber* as the type of the genus, since it could be readily recognized using Eidam's original description, and, since a neotype collection had been made for the species. *Arachniotus candidus*, on the other hand, was not recognizable from the description which could apply to any number of genera with poorly differentiated, hyaline peridial hyphae.

Dale's (1903) developmental study of *Arachniotus candidus* in culture illustrates an anamorph which closely resembles *Arthrographis cuboidea* (see FIG 5.6b). She stated that cultures derived from these conidia would give the characteristic *Arachniotus candidus* teleomorph. This connection is puzzling, and clarification of the taxonomic position of this taxon must await the availability of further isolations. A specimen on roe dung from Kew appears to contain the teleomorph of *A. candidus*, but this collection is mixed with other fungi. Sydow's collection, 4031 which I have examined from several herbaria (K, TRTC) also appears to represent *Arachniotus candidus* in having snow-white ascomata, and tiny, smooth-walled, oblate ascospores. Since these collections contain many fungi (including *Oncocladium flavum* in the Sydow material) it is

impossible to link, with certainty, an anamorph to the teleomorph. Morphology of the ascospores would place *Arachniotus candidus* in *Gymnascella*. *A. ruber* is the only described species in the genus at this time. However, an isolate made by Benjamin (1956) (RSA 202) has similar pulley-wheel shaped ascospores and could be accommodated in *Arachniotus* as it is presented here.

*Arachniotus ruber* (Van Tieghem) Schroeter, 1893 KryptogamenFlora von Schlesiens **3**:211.

FIG 5.2, 5.3, 5.2e

**Type material:** NEOTYPE (*cultura desiccata*) **NY** O-3314. (soil, Britain). (*fide* Orr, Ghosh and Roy, 1977).

≡*Gymnoascus ruber* Van Tieghem, Bull. Soc. Bot. Fr. **24**:159, 1887 (Basionym).

≡*Pseudoarachniotus ruber* (Van Tieghem) Orr, Ghosh and Roy, Mycologia **69**:153, 1977.

=*Pseudoarachniotus trochleosporus* Kuehn and Orr, Mycologia **64**:58, 1972.

**Ascomata:** orange to red, discrete or undifferentiated, spherical, 20-300*u*m diam., sometimes confluent (on natural materials ascomata may develop to a diam. of 1000*u*m). **Ascospores:** orange to yellow, smooth, "pulley-wheel" shaped with an equatorial groove bordered by distinct ridges, poles thickened, 2.8-4.4 x 4.0-6.6*u*m. **Asci:** hyaline, ovoid, 7.0-10 x 10-13*u*m. **Peridial hyphae:** present or absent, often sparse, smooth, thin-walled, septate, constricted at septa, sometimes irregular in width, 1.0-3.3*u*m. **Anamorph:** Van Tieghem's original description noted a *Verticillium*-like anamorph but this was probably a contaminant. Kuehn & Orr (1964) noted production of hyaline arthroconidia, but these were never observed in the present study. **In culture:** [UAMH 3543, 4763]. **PDA 25°C** At first pale pink to pinkish orange, slightly granular; reverse becoming pale yellowish orange. After 30 days obverse is deep orange to rusty orange or brown; reverse deep orange to chestnut brown. On OAT, growth is pale yellow and scant. [UAMH 4763]. CER 42/25°C pale rose, to white or pale tan, fuzzy becoming granular; reverse orange-red. DSA 42/25°C white to off-white, scant; reverse uncolored. PYE 42/25°C thick, dense, white

to pale tan; reverse tan.

**Notes:** This beautiful and distinctive species is rarely isolated. Domsch, Gams and Anderson (1980) refer to its isolation from soil, plant litter, rhizosphere of wheat and hazel nut, as well as freshwater streams and various types of dung. My only isolation of this species came from coyote dung incubated at 5°C where it grew abundantly and fruited in quantity. At higher temperatures this species was not able to compete with other coprophilous fungi. Low temperature primary isolation procedures (which are more time consuming) may indicate that this species is more widespread and more common than the literature implies.

**Material examined: NY** B173/?/? "dried cultures from Orr (1964)"; Massee/dog dung/England, Drawings (1905); O-3158/soil/Holland; O-3366/soil/Germany, Gams C514; Domsch C925/soil/East Germany (dessicated culture); **UAMH** 3543/neotype strain as cited; 4763/dung/Alberta, coll. Currah; as *Gymnoascus* sp.: **FH** ?/dog dung/Argentina (with *Gymnoascus reessii*); **TRTC** Wight 276/soil/Jamaica (natural material); as *Pseudoarachniotus ruber*: **FH** O-3266/soil/East Germany (Domsch 925).

## SPECIES EXCLUDED OR REFERRED TO OTHER GENERA

*Arachniotus albicans* Apinis, Mycol. Pap. **96**:45, 1964

≡*Amauroascus albicans* (Onygenaceae).

*Arachniotus aureus* (Eidam) Schroeter, KryptogamenFlora von Schlesiens **3**:210, 1893

≡*Amauroascus aureus* (Onygenaceae).

*Arachniotus flavoluteus* Kuehn and Orr, Mycologia **51**:864, 1959

=*Gymnascella dankaliensis*.

*Arachniotus glomeratus* Muller and Pacha-Aue, Nova Hedwigia **15**:544, 1968 Taf. 76-78.

≡*Arachnotheca glomerata* (Excluded Genera, Chapter 8).

*Arachniotus hebridensis* Apinis, Mycol. Pap. **96**:41-42, 1964

Type strain in UAMH (3089) is a *Geomyces* sp. Holotype at CMI (sandy

pasture soil, Hebrides) was not examined. Udagawa's isolate under this name (from pig dung, Guadalcanal) is keratinolytic and probably a new species of Onygenaceae.

*Arachniotus indicus* Chattopadhyay and Das Gupta, Trans. Brit. mycol. Soc. **42**:72, 1959

=*Talaromyces flavus* (Klocker) Stolk and Samson var. *flavus* Stolk and Samson, CBS Stud. Mycol. **2**:11, 1972 (Eurotiales).

*Arachniotus intermedius* Apinis, Mycol. Pap. **96**:45, 1964

=*Talaromyces flavus* var. *flavus* Stolk and Samson, CBS Stud. Mycol. **2**:11, 1972 (Eurotiales).

*Arachniotus lanatus* (Wallroth) Apinis, Mycol. Pap. **96**:39, 1964

(?) Hughes (1968) observed the holotype and reported that it had no ascospores. Apinis (1964) figured ascospores from the holotype. Some hyphae resemble those of *Nannizziopsis vriesii* (Onygenaceae).

*Arachniotus lectardii* Nicot, Bull. Mycol. Soc. Fr. 85:319, 1969

≡*Eleutherascus lectardii* (Nicot) von Arx, Persoonia **6**:378, 1971 (Pezizales).

*Arachniotus niger* (Schroeter) Kuehn *et al.*, Mycopathol. et Mycol. Appl. **25**:106, 1965

≡*Amauroascus niger* (Onygenaceae).

*Arachniotus purpureus* Muller and Pacha-Aue, Nova Hedwigia **15**:552, 1968

≡*Talaromyces purpureus* (Muller and Pacha-Aue) Stolk and Samson CBS Stud. Mycol. , **2**:57, 1972 (Eurotiales).

*Arachniotus reticulatus* Kuehn, Mycologia **49**:57, 1957

≡*Amauroascus kuehnii* (Onygenaceae).

*Arachniotus striatosporus* Barron and Booth, Can. J. Bot. **44**:1060, 1966.

≡*Byssoascus striatosporus* (Myxotrichaceae).

*Arachniotus terrestris* Raillo, Zentral. Bakt. Inf. **2, 78**:521, 1929 (?, no type material).

*Arachniotus trachyspermus* Shear, Science **16**:138, 1902 illus in Shear *et al.*, 1931 USDA Tech. Bull. No.258:13

≡*Talaromyces trachyspermus* (Shear) Stolk and Samson, CBS Stud. Mycol. **2**:32, 1972 (Eurotiales).

*Arachniotus trisporus* Hotson, Mycologia **28**:500, 1936

=*Byssochlamys nivea* Westling, Svensk. Bot. Tidskr. **3**:125, 1909 *fide* Kuehn, Mycologia **49**:55-67, 1957 (Eurotiales).

*Arachniotus verrucosus* (Eidam) Kuehn *et al.*, Mycopathol. et Mycol. Appl. **25**:103, 1965

=*Amauroascus mutatus* (Onygenaceae).

*Arachniotus volatilis-patellis* Orr and Kuehn, Mycologia **64**:61, 1972

≡*Amauroascus volatilis-patellis* (Onygenaceae)

**GYMNASCELLA** Peck, 1885

J. Mycol. **1**:57.

**Type species:** *Gymnascella aurantiaca* Peck *op. cit.*

=*Narasimhella* Thirumalachar and Mathur, 1966.

=*Petalosporus* Ghosh, Orr and Kuehn, 1963.

=*Plunkettomyces* Orr, 1977.

=*Pseudoarachniotus* Kuehn, 1957.

=*Waldemaria* Batista, 1960 *fide* von Arx, 1971.

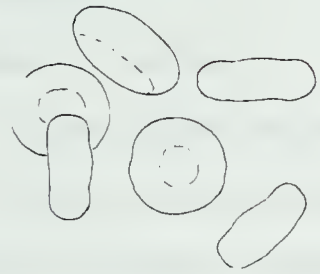
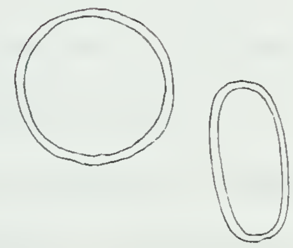
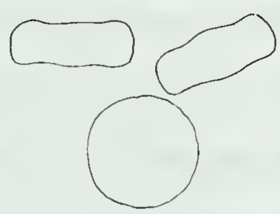
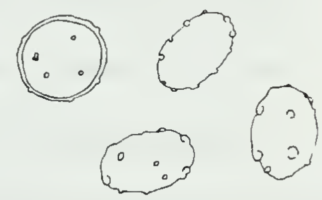
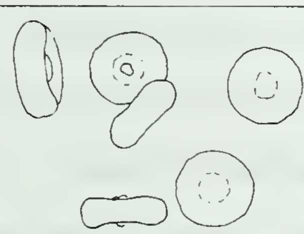
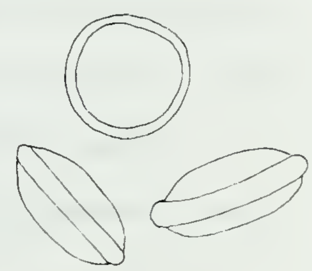
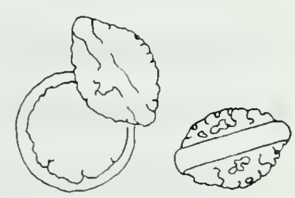
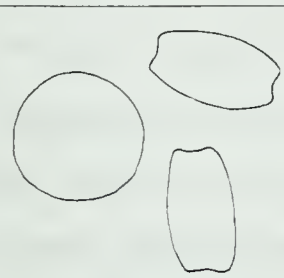
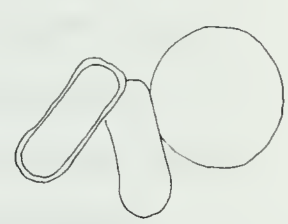
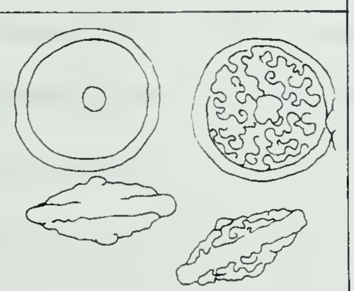
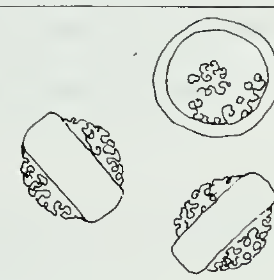
**Ascomata:** pale yellow or brightly colored, orange, orange-brown, red, red-orange; ±globose when discrete; often not differentiated into discrete ascomata in agar cultures. **Ascospores:** hyaline, or lightly colored in shades of yellow or orange, oblate, ±polar and/or equatorial thickenings, smooth-walled or somewhat irregular to lumpy, not punctate. **Asci:** hyaline, ovoid to spherical, evanescent or occasionally persistent, 8-spored. **Peridial hyphae:** thin-walled, ±uniform in diameter, similar to vegetative hyphae and forming a telaperidium; or with some irregularly shaped and irregularly thick-walled elements comprising an incompositothecium. **Appendages:** lacking. **Thallism:** homothallic. **Anamorph:** uncommon; arthroconidial when present.

**Notes:** Most species treated here in *Gymnascella* have been regarded at one time or another as species of *Arachniotus*. *Gymnascella* is probably an artificial collection of species. The ascospores are the most important source of information for distinguishing species since accessory structures are variable in morphology and occurrence. Peck described *Gymnascella aurantiaca* based on a

specimen which was deposited at NYSM. This material is now insufficient to recognize the species and Von Arx felt it probably represented *Gymnoascus reessii*. An isotype is located at TRTC. Upon examination of this material, I found it to represent the same taxon as *Arachniotus aurantiacus* Kamyschko. Since *Gymnascella* has priority over *Arachniotus*, I have placed all oblate-ascospored species formerly in *Arachniotus*, in *Gymnascella*. *Arachniotus*, typified by *A. ruber*, is reserved for species with a double equatorial band.

TABLE 5.2

ASCOSPORE MORPHOLOGY IN THE SPECIES OF GYMNASCELLA

| Species | Ascospores | Species | Ascospores |
|---|---|---|---|
| G. afilamentosa |  | G. devroeyi |  |
| G. aurantiaca |  | G. hyalinospora |  |
| G. (?) candida |  | G. littoralis |  |
| G. citrina |  | G. marginospora |  |
| G. confluens |  | G. nodulosa |  |
| G. dankaliensis |  | G. punctata |  |

*Gymnascella afilamentosa* (Orr and Kuehn) comb. nov. .

FIG 5.4, PL 5.4c, 5.5a

**Type material:** HOLOTYPE **NY** DPG 115 (soil, Utah).

≡*Petalosporus afilamentosus* Orr and Kuehn, Mycologia **64**:62, 1972 FIG 9 and 10. (Basionym).

**Ascomata:** yellow to yellowish brown, rarely discrete, ±globose, to 300*u*m diam. **Ascospores:** pale golden yellow, oblate, smooth, thick-walled, poles slightly depressed with a central thickening, perimeter slightly flattened, 2.0-3.0 x 4.5-5.0*u*m. **Asci:** thin-walled, evanescent, ascospores adhering in characteristic petaloid pattern, to 12*u*m diam. **Anamorph:** lacking. **In culture:** [UAMH 3427]. **PDA 25°C** At first hyaline to faint yellow; reverse pale yellow; obverse soon becoming bright yellow, flocculent and radiately sulcate; At 25 days surface bright yellow with pale buff brown patches developing in central area, thick and felty; reverse pale yellowish brown. Plate covered in 20 days. On OAT mat becomes orange to rusty brown, yellow at the perimeter. CER 28/25°C ochre yellow, granular and irregular; reverse pale yellow. DSA 42/25°C yellow, granular forming concentric zones; reverse cream. PYE 35/25°C yellow, deep felty mat; reverse yellow-brown.

**Notes:** This species is easily confused with *Gymnascella aurantiaca*. The petaloid arrangement of the ascospores within the ascus in *G. afilamentosa* is the primary character differentiating the two taxa. *G. aurantiaca* ascospores adhere in very compact clusters, and are slightly larger. Cultures of the two species are similar in color but differ in surface texture and growth rate. *G. aurantiaca* is faster growing and has a wispy or less dense mat than *G. afilamentosa*. Reverse coloration also differs between the two species, being yellowish tan in the latter species and yellowish orange in *G. aurantiaca*.

**Material examined: NY** O-3345/coyote dung/Utah; O-3229/lizard dung/Utah; O-3346/mouse spleen/Utah; O-3533/soil/Utah; O-3427 (O-2601)/soil/Utah (=UAMH 3427, from Orr).

*Gymnascella aurantiaca* Peck, 1885 J. Mycol. **1**:57.

FIG 5.5, PL 3.1f, 5.3a,c,d, 5.4a

**Type material:** HOLOTYPE (natural material). **NYS** Peck (plant debris and bones, New York). (ISOTYPE at **TRTC**).

=*Gymnoascus aurantiacus* (Peck) Saccardo, Sylloge Fungorum **8**:823, 1889 (Basionym).

=*Myxotrichum aurantiacum* (Peck) Saccardo, Sylloge Fungorum **4**:319, 1886.

=*Pseudoarachniotus aurantiacus* Kamyschko, Nov. Sist. niz. Rast. **4**:224, 1967.

=*Gymnascella aurantiaca* (Kamyschko) von Arx, Persoonia **6**:373, 1971.

=*Arachniotus verruculosus* Orr and Kuehn, Mycologia **64**:62, 1972.

=*Gymnascella kamyschkoi* Orr, Ghosh and Roy, Mycologia **69**: 137, 1977.

**Ascomata:** pale yellow to golden yellow, (orange brown), clusters of asci form among hyphae which are mostly undifferentiated from surrounding vegetative mycelium; ascomata may appear as discrete, ±spherical structures, or may not be visibly different from the vegetative mat. **Ascospores:** golden-yellow, oblate, slightly concave; polar surfaces irregular, with or without a distinct boss, or bulge; rim flattened, 2.5-3.5 x 4.0-6.0(-7.0)*u*m. **Asci:** globose or ellipsoid, 8.0-12*u*m diam. **Peridial hyphae:** hyaline to pale golden yellow, mostly resembling vegetative hyphae but occasionally with ±thick-walled elements. **Anamorph:** lacking. **In culture:** [UAMH 3529] **PDA 25°C** Mycelium at first hyaline, becoming pale yellow, appressed to slightly granular to tomentose; reverse pale yellow; obverse soon becoming golden yellow, pubescent and remaining smooth; reverse orange yellow to tan yellow. Plate covered in 15 days. On OAT the mature mat is pale yellow, granular, scant with a diffusible yellow pigment. CER

49/25°C Orange, slightly pubescent; reverse pale orange. DSA

42/25°C Yellow brown, granular in a concentric zone, elsewhere pale yellow, scant; reverse concolorous. PYE

Cream white, felty; reverse pale yellow.

**Notes:** *Gymnascella aurantiaca* is a relatively common species and although it has been found in a variety of habitats, it appears to be primarily a coprophilous fungus. The sparse nature of the peridium necessitates careful

study of the ascospores to distinguish this species from *Gymnascella afilamentosa* (see above) and *Gymnascella citrina*. The ascospores of the latter species are rhomboidal when viewed on edge and are lemon yellow rather than golden yellow. Besides the type material of *Arachniotus verruculosus* (O-3175, from soil, Utah), I have seen one other collection assignable to this name (TRTC "*Rosellinia schumacheri*" E. Marchal, from dog dung, Brussels). Ascospores are slightly larger and have very slight irregularities in the walls (possibly shallow depressions). Since *Gymnascella aurantiaca* contains some variants with respect to peridial hyphae and color of the ascospores and vegetative mycelium, I prefer to consider this taxon a synonym of *Gymnascella aurantiaca*. *Arachniotus verruculosus* may emerge as a distinct species with the availability of more isolates.

**Material examined: NYSM** (also in TRTC 32167) type material as cited; as *Gymnoascus*: **U** 178821B/owl pellet/Holland; **NY** O-3175/soil/Utah (type of *Arachniotus verruculosus*); **TRTC** 33053/lab contaminant/Ontario; 37072/in culture/Ontario; Cooke 2461/?/U.S; Emmons/bat dung dust/Georgia; **NY** as *Gymnoascus uncinatus* O-I-9/soil/Italy; as *Gymnascella kamyschkoi* **NY** O-790/sheep dung/California; O-3005/soil/U.S.S.R.; as *Rosellinia schumacheri* **TRTC** E. Marchal/dog dung/Brussels (?=*Arachniotus verruculosus*; **UAMH** neotype strain 3529 from Von Arx as 603.67 (1972).

*Gymnascella citrina* (Massee and Salmon) Orr, Ghosh and Roy, 1977 Mycologia **69**:126.

FIG 5.7, PL 5.2a

**Type material:** NEOTYPE (*cultura desiccata*) **NY** O-195 (soil, California) (Designated by Orr *et al.*, *op. cit.*).

≡*Arachniotus citrinus* Massee and Salmon, Ann. Bot. **16**:162, 1902 FIG 86 and 88 (Basionym).

≡*Pseudoarachniotus citrinus* (Massee and Salmon) Kuehn, Mycologia **49**:699, 1957.

**Ascomata:** white at first, becoming deep lemon-yellow, 0.5-1mm, often confluent. **Ascospores:** lemon-yellow, smooth, thick-walled, oblate with thickened

poles and an equatorial rim, almost rhomboidal in side view, 3.0-4.5 x 4.0-6.0*um*. **Asci:** hyaline, ovoid to subglobose, 8.0-15*um* diam. **Peridial hyphae:** scanty to absent, delicate, smooth, septate, 3.0*um* diam. **Anamorph:** lacking. **In culture:** [UAMH 3073, 3545]. **PDA 25°C** Mycelium white, fuzzy at first with pale yellow reverse; becoming lemon yellow in central region where mycelium becomes heaped and fluffy; margin remains white at 30 days. Plates were not covered after 30 days. On OAT, growth is bright citrine yellow, granular in central zone becoming felty toward the perimeter. [UAMH 3545]. CER 35/25°C ochre and felty at centre, grading into lemon-yellow, thinning to granular growth at perimeter; reverse bright yellow. DSA 42/25°C granular, yellow-brown; reverse yellow. PYE 42/25°C clay-brown and lemon-yellow zones, thick felty; reverse bright yellow.

**Notes:** The bright, lemon-yellow color of the mycelial mat is a distinctive cultural feature. Von Arx (1971) lists *Arachniotus confluens* as a synonym of this species. *Gymnascella confluens*, as described by Sartory and Bainier (1913 a and b), and neotypified by Apinis (1964),is easily distinguished from *Gymnascella citrina* on the basis of ascospore morphology.

Massee and Salmon (1902) observed this species on kangaroo dung. It is difficult to determine the characteristic habitat(s) of this taxon until more isolates are available.

**Material examined: FH** O-3056/dog/Texas; O-3339/?/?; O-3340/?/?; **UAMH** 3073/soil/Tennessee; 3545/soil/U.S.A., from Von Arx, CBS 114.54 (1972).

*Gymnascella confluens* (Sartory and Bainier) comb. nov. .

<u>FIG 5.8, PL 5.4b,d</u>

**Type material:** NEOTYPE (*cultura desiccata*) **BDUN** 375 (dung, England). (*fide* Apinis, 1964.

=*Gymnoascus confluens* Sartory and Bainier, C. R. Soc. Biol. Paris **74**:498-500, 1913; Bull. Soc. Mycol. Fr. **29**:261-272 , 1913 PL XII FIG 1-8. (Basionym).

=*Arachniotus confluens* (Sartory and Bainier) Apinis, Mycol. Pap. **96**:37-39,

1964.

=*Arachniotus desertorum* Moustafa, Trans. Brit. mycol. Soc. **61**:392-393, 1973 FIG 1-6.

=*Pseudoarachniotus desertorum* (Moustafa) Orr, Ghosh and Roy, Mycologia **69**:158, 1977.

**Ascomata:** red-brown, 20-80*um*, confluent into tufts (yellow-brown) up to 500*um* diam. **Ascospores:** orange to yellow or brick-red (slightly encrusted) slightly lenticular to oblate, with a broad, shallow equatorial depression; thick-walled, smooth (or with granular material adhering), 3.3-4.6 x 5.0-6.5(-7.5)*um*. **Asci:** globose to subglobose or somewhat pyriform, 10-13*um* diam. **Peridial hyphae:** mostly hyaline, undifferentiated, some yellow-brown, branched, septate, slightly thick-walled elements, these ±heavily encrusted and sometimes constricted at septa. **Anamorph:** arthroconidia, 5.0-6.0 x 7.5-9.5*um* (infrequent). **In culture:** [UAMH 3565, 3763]. **PDA 25°C** At first white, cottony with pale yellow diffusible pigment; becoming yellowish to orange and finally with some olive tints, aerial mycelium scant; after 30 days reverse is brown. Plates covered in 25 days. On OAT aerial mycelium is yellowish to brown and granular; margin pale yellowish tan.[UAMH 3565]. CER 49/25°C cream to orange brown, wispy to slightly felty; reverse pale yellowish tan. DSA 42/25°C yellowish white, scant; reverse concolorous. PYE 28/25°C cream to pale brownish yellow, felty; reverse brown.

**Notes:** I have combined *Gymnascella confluens* and *Arachniotus desertorum* here. The type of *A. desertorum* was from halomorphic soil, Kuwait. (CBS 634.72 (IMI 163480). No holotype was designated by Moustafa, but the type strain is darker in color on most media and the ascospores are slightly larger (pole to pole) than the type strain of *Gymnascella confluens*. Differences between these strains do not merit maintaining them as distinct species. In an Alberta isolate from carnivore dung, the deep, rusty brown color of the fertile mycelium is very distinctive. The red color and equatorial depression on the ascospores make *Gymnascella confluens* similar to *Arachniotus ruber*. However the latter species is orange red on natural substrata and artificial media and close examination of the ascospores should provide a reliable distinction.

*Gymnascella dankaliensis* is also similar in color but examination of the equatorial regions of both species should provide sufficient information to distinguish between the two taxa. *Gymnascella confluens* is predominantly coprophilous.

**Material examined:** as *Pseudoarachniotus desertorum*: **NY, FH, UAMH** O-1160 (=UAMH 3763)/halomorphic soil/Kuwait; as *Pseudoarachniotus* sp.: **RSA** 1240/pack rat dung/California; as *Arachniotus ruber*: **TRTC** 35217/carnivore dung/Ontario; as "Gymnoascaceae" **TRTC** 31522/carnivore dung/Wyoming; as *Arachniotus confluens*: **ATCC** 21024/dung/Pakistan; **UAMH** 3565 from CBS 352.66 derived from BDUN 375 (type strain).

*Gymnascella dankaliensis* (Castellani) comb. nov. .

FIG 5.9, PL 3.1c, 5.5b,c,e,f, 5.7c

**Type material: UAMH (type strain)** 3552 (camel skin, Italy). (possibly no holotype).

≡*Trichophyton dankaliense* A. Castellani, Jour. Trop. Med. Hyg. **40**:315, 1937 Pl. 1-3. (Basionym).

≡*Arachniotus dankaliensis* (Castellani) van Beyma, Antonie van Leeuwenhoek **8**:107, 1942.

=*Arachniotus flavoluteus* Kuehn and Orr, Mycologia **51**:864, 1959.

≡*Pseudoarachniotus flavoluteus* (Kuehn and Orr) Orr, Ghosh and Roy, Mycologia **69**:155, 1977.

=*Waldemaria pernambucensis* Batista *et al.*, Atas Inst. Micol. (Recife) I:6, 1960 *fide* von Arx *loc. cit.*

=*Pseudoarachniotus flavus* Thirumalachar and Mathur, Mycopathol. et Mycol. Appl. **40**:97, 1970 *fide* von Arx *loc. cit.*

=*Pseudoarachniotus halophilus* Pawar *et al.*, Mycopathol. et Mycol. Appl. **40**:102, 1970 *fide* von Arx *loc. cit.*

=*Pseudoarachniotus terrestris* Thirumalachar and Mathur, Mycopathol. et Mycol. Appl. **40**:102 , 1970 *fide* von Arx *loc. cit.*

=*Pseudoarachniotus thirumalacharii* Mathur, Mycopathol. et Mycol. Appl. **40**:101 , 1970 *fide* von Arx *loc. cit.*

=*Pseudoarachniotus roseus* Kuehn, 1957 *fide* von Arx, Persoonia **6**:372, 1971.

**Ascomata:** orange-yellow to brownish orange clumps of ascospores surrounded by ±differentiated peridial hyphae, 80-600*u*m diam. **Ascospores:** yellow to orange or red-brown, oblate with equatorial and polar thickenings, surface irregular, (3)4.3-5.3 x 6.0-8.0*u*m. **Asci:** 8.2-12*u*m diam. **Peridial hyphae:** either undifferentiated from vegetative hyphae or occasionally thick-walled, somewhat gnarled, roughened, irregular hyphae. **Anamorph:** arthroconidia reported but not observed here. **In culture:** [UAMH 1919, 1995, 3532, 3552]. **PDA 25°C** Mycelium at first white with yellow tinge, tomentose becoming felty to funiculose with abundant aerial mycelium; soon radiately sulcate, yellow to yellowish brown with scattered patches or knots of darker orange brown (indicative of ascospore production). Some strains with little surface mycelium and tinged olive green. Plates covered after 25-30 days. On OAT orange-brown to rusty brown with age, granular; reverse pale orange-brown from diffusible pigment. ?UAMH 3532?. CER 56/25°C tan brown to granular; margin pale brown to cream, reverse concolorous. DSA 49/18°C white with hirsute brown centre; reverse concolorous. PYE 42/25°C reddish yellow, reticulate tufted; reverse reddish brown.

**Notes:** This species is combined here with *Arachniotus flavoluteus*. Distinction was based on ascospore color and size, but intergrading shades and sizes occur. I feel that the distinctive (and consistent) ascospore shape found in isolates under either name should be weighed against these variable characters. This species may be confused with *Gymnascella devroeyi* in gross cultural morphology. Spores of that species are much larger, lack the distinctive acute, thickened equatorial margin and are smooth-walled. Kuehn (1958) and Van Beyma (1943) refer to the production of round, brown hulle cells, 10-12*u*m diam. These were never observed in the present study. This species is apparently cosmopolitan and frequently coprophilous. Also found in other materials of animal origin.

**Material examined: UAMH** 1919/soil/Japan; 3552/camel skin/Italy (type strain received from von Arx CBS 117.38 (1972); 3532/soil/Sudan from CDC

(1972); **NY** O-902/ulcerated chicken gizzard/Arizona; O-3467/human foot lesion/California; IMUR 924/human auditory canal/Brazil; as *Arachniotus* or *Pseudoarachniotus flavoluteus*: O-31/bat dung/India; O-121/bird dung/India; O-134, -1167, -1168, -1173, -1174/soil from cow shed/India; O-483/lizard dung/California; O-728/soil/Arizona (type of *Arachniotus flavoluteus*); O-1176/?/?; O-3172/human/India; O-3280/soil/West Pakistan; O-3286/human/India; O-3291/bat dung/India; O-3573/fox dung/India; O-3647/soil/Argentina; **TRTC** M 7143/soil/Egypt; as *Pseudoarachniotus roseus* **NY** O-433/?/California; O-731/rodent/Arizona; O-1123/dog hair/Dutch Antilles; O-1176/?/? O-1194/dog tick/SW Africa; O-2010/human skin/India; O-2515/soil/France; O-3091/soil/Pakistan; O-3180/soil/India; O-3189/soil/Somalia; O-3203/human ear/Brazil; O-3361/soil/California; O-3464/human foot/California; O-3524/human toenail/California; O-3538/ear canal/Curacao; O-3579/?/?.

*Gymnascella devroeyi* (Orr) comb. nov. .

FIG 5.10, PL 5.1c

**Type material:** HOLOTYPE (*cultura desiccata*). **NY** O-3485 (soil, Somalia).

=*Disarticulatus devroeyi* Orr, Mycotaxon **6**:35, 1977 (Basionym).

=*Disarticulatus indicus* Orr, Mycotaxon **6**:38, 1977.

=*Arachniotus devroeyi* (Orr) von Arx, Persoonia **9**:397, 1977.

**Ascomata:** yellow-orange to orange, ±globose, 30-175*u*m diam. **Ascospores:** yellow-orange to orange or reddish brown, smooth, thick-walled, oblate, 3.4-4.5 x 4.9-7.9*u*m. **Asci:** globose, ellipsoid, 9.5-15(17)*u*m diam. **Peridial hyphae:** variously shaped, thick-walled (0.6-1.4*u*m) cells, 3.8-13 x 17-26*u*m, some with interior surface decorated with lateral grooves, disarticulating readily; forming an incompositothecium. **In culture:** [UAMH 3136]. CER 21/25°C bright rusty orange, zonate, evenly granular; reverse deep rusty-red. DSA 49/25°C scattered granular patches of mycelium; reverse colored by abundant orange diffusible pigment. PYE 35/25°C deep brownish red, granular: reverse appearing black.

**Notes:** This is an extremely distinctive but rarely isolated species. The comparatively large ascospores and unique, thick-walled, disarticulating peridial

hyphae are not so pronounced in any other species of *Gymnascella*. *Disarticulatus indicus* is considered a synonym since the type strain exhibits only minor differences in size of the disarticulated peridial hyphae. Unfortunately, cultures of this species were not studied in detail for this paper.

**Material examined: FH, NY** O-3485/soil/Somalia (type as cited); **NY** 3475/soil/Somalia; as Gymnoascaceae **RSA, UAMH** 1481 (=UAMH 3136)/rabbit dung/Colorado; as *Disarticulatus indicus* **FH** /O-1089/bat dung/India; **NY** O-951/soil/India; **FH, NY** O-1130, -1131/soil/India.

*Gymnascella hyalinospora* (Kuehn, Orr and Ghosh) comb. nov. .

FIG 5.11, PL 5.7d

**Type material:** Type strain **RSA** 1529 and **UAMH** 3155. (Possibly no holotype).

=*Pseudoarachniotus hyalinosporus* Kuehn, Orr and Ghosh, Mycopathol. et Mycol. Appl. **14**:215-229, 1961 (Basionym).

=*Arachniotus hyalinosporus*, (Kuehn, Orr and Ghosh) Apinis, Mycol. Pap. **96**:41, 1964.

=*Narasimhella hyalinospora* (Kuehn, Orr and Ghosh) von Arx, Persoonia **6**:373, 1971.

=*Rollandina hyalinospora* (Kuehn, Orr and Ghosh) Roy *et al.*, Kavaka, 1977 (not seen).

**Ascomata:** discrete ascomata absent, groups of asci 20-88*um*. **Ascospores:** hyaline to pale yellow, ovoid to oblate, appearing smooth but with scattered warts visible under oil, (1.8)2.2-2.5 x 2.5-3.3*um*. **Asci:** ±globose, 5.5-8.8*um* diam. **Peridial hyphae:** undifferentiated, or with some slightly thick-walled and pigmented hyphae, 3.5-5.0*um*. **Anamorph:** scattered reports of the occasional occurrence of arthroconidia but none observed during this study. **In culture:** [UAMH 3125, 3126, 3127, 3148, 3155]. **PDA 25°C** At first glabrous, white with no diffusible pigment; becoming off-white to pale yellow with some green tints, funiculose and slightly radiately wrinkled; reverse yellowish becoming orange brown. Colonies commonly sectoring into: 1. yellowish orange, glabrous; reverse opaque; and 2. yellowish, cottony, reverse reddish brown. [UAMH

3155]. CER 77/25°C pale yellow with darker yellow patches, felty; reverse red brown. DSA 42/25°C pale cream, growth sparse; reverse uncolored. PYE 56/25°C yellow with distinct greenish areas; reverse dark reddish brown.

**Notes:** The original description (Kuehn *et al.*) explains that: "racquet mycelium often form upright fascicles or coremiform stalks to 1 cm in length - often with green pigment." The habit of developing apical caps of yellow fertile tissue may have led to the disposition of this taxon in *Rollandina*. *Rollandina capitata* was described by Patouillard in 1905 for material found on plant debris collected in North Viet Nam (Tonkin). He placed it in the Gymnoascaceae, since the "ascigerous glomerules resemble fruit bodies of Gymnoascaceae." Benjamin (1956) emended the genus after carefully analysing the type material (FH) by making sections of the entire fruiting structure (consisting of a sterile stalk and a capitulum containing ascospores). In a reexamination of this material Apinis (1968) determined that there were two species making up the fruiting body, a conclusion which is supported in part in this study (in fact, there may have been more than 2 species present). The ascospores found in the capitulum resemble those of *Gymnascella marginospora*. However, the original name was applied to both (if not more than 2 species present) fungi comprising the stalked fruiting body. Von Arx (1977) suggested that *Rollandina* be considered a *nomen confusum* and this is supported here. Apinis *op. cit.* placed two keratinolytic species in *Rollandina*. These are discussed under *Nannizziopsis* of the Onygenaceae.

**Material examined:** **RSA** 1486 (=UAMH 3141)/lizard dung/Mexico; 1503/lizard dung/Mexico; **UAMH** 1605/soil/California; 3148 (=RSA 1502); 3137 (=RSA 1482); 3126 (=RSA 1443); 3125 (=RSA 1442); 3127 (=RSA 1444)/lizard dung/Mexico; 3155 (=RSA 1529)/guinea pig dung/India from NRRL 2881 (type strain from Benjamin (1969); 3120 (=RSA1437)/lizard dung/Mexico; **NY** O-733 (=RSA 1529, =NRRL 2881/guinea pig dung/India (type strain); **RSA** 1503/lizard dung/Mexico; as *Rollandina hyalinospora* **NY** O-57/mouse dung/India; O-254; O-269/cheese/India; O-283/rat dung/India; O-285; O-288/soil/California; O-311/fox dung/California; O-757/lizard dung/California; O-821/goat dung/India; O-874/pack rat dung/California; O-3052/gull dung/Mexico; O-3265/soil/India;

O-3329/soil/Kentucky; O-3338/soil/Arkansas; O-3368/soil/Uruguay; O-3425/feathers/Queensland; O-3450/soil/Italy; O-3478/soil/Belgium; O-3650/soil/England.

*Gymnascella littoralis* (Orr) comb. nov. .

FIG 5.12, PL 5.2b

**Type material:** HOLOTYPE *(cultura desiccata)*. **NY** O-3053 (conch shell, British Columbia).

=*Plunkettomyces littoralis* Orr, Mycotaxon **6**:33, 1977 (Basionym).

=*Arachniotus littoralis* (Orr) von Arx, Persoonia **9**:397, 1977.

**Ascomata:** yellow to orange-brown, globose, 35-155*u*m diam., often confluent. **Ascospores:** yellow-brown to orange-brown, smooth, thick-walled, oblate with equatorial rim, 0.3-0.6*u*m wide, 2.9-3.8 x 4.2-5.7*u*m. **Asci:** ±globose, to 11*u*m diam. **Peridial hyphae:** hyaline or yellow, simple or branched, smooth slightly thick-walled, 2.1-3.3*u*m diam. **Anamorph:** smooth-walled arthro- and aleurioconidia, 2.0-2.8 x 3.5-7.0*u*m. **In culture:** [UAMH 3885]. **PDA 25°C** At first hyaline to white, very slow to start; reverse uncolored; becoming pale rosy yellow or orange, closely appressed; reverse tinged orange. Finally peach-colored with pale brown patches; reverse orange brown. Plate covered in 20 days. CER 14/25°C orange-pink in centre, elsewhere pale orange yellow, fuzzy; reverse yellow. DSA 42/25°C pale with orange-red tinge, sparse, fuzzy. PYE 14/25°C creamy yellow, felty or fuzzy; reverse orange brown.

**Notes:** Known only from substrates obtained from marine habitats, west coast of North America.

**Material examined: NY, FH, UAMH** O-3053 (=UAMH 3885)/conch shell/British Columbia (type strain); **FH, NY** O-3050/crab shell/Mexico; O-3051/snail shell/British Columbia; O-3074/crab shell/California; O-3078/coral/Mexico; **FH** O-3076/insect carapace/Mexico; **NY** O-3065/red alga/California; **UAMH** 3863 (=O-3055)/sea anemone/Mexico.

*Gymnascella marginospora* (Kuehn and Orr) comb. nov. .

5.13, PL 5.6a,b,c, 5.7

**Type material:** Possibly no type.

=*Pseudoarachniotus marginosporus* Kuehn and Orr, Mycopathol. et Mycol. Appl. , **19**:257, 1963 (Basionym).

=*Narasimhella poonensis* Thirumalachar and Mathur, Sydowia **19**:184, 1965.

=*Arachniotus marginosporus* (Kuehn and Orr) Udagawa, Trans. Mycol. Soc. Jap. **10**:103-104, 1970.

**Ascomata:** spherical, 50-150*u*m diam. when discrete; often no more than clusters of ascospores among vegetative hyphae. **Ascospores:** yellow-orange, oblate, (sometimes appearing lenticular in side view); walls thick, smooth or slightly rough (due to surface convolutions of ascospore wall), with a slender equatorial rim (2.2)2.5-3.0*u*m x 3.0-3.8(4.4)um. **Asci:** globose to subglobose, 7.0-8.0*u*m diam. **Peridial hyphae:** mostly undifferentiated from vegetative hyphae but some smooth, thick-walled elements occur in some isolates. ANSM QM 1327 from linen, (and ATCC "Shear") has well-developed, thick-walled hyphae scattered among the ascospores. These are illustrated in figure 5.13. **Anamorph:** few hyaline arthroconidia, 2.2-4.4 x 5.5-7.0*u*m. [UAMH 1902, 3533, 3534]. **PDA 25°C** Creamy white and slightly powdery at first; reverse uncolored; becoming pale yellow with scattered spots of orange (most numerous near the centre), cottony and strongly funiculose, concentrically zonate; reverse yellow-brown to brown. Plates covered in 7-9 days. On OAT, rusty orange felty or granular, cracking; reverse dark orangish tan. [UAMH, 1902]. CER 14/25°C numerous, crowded, spherical, orange, minutely stalked tufts of ascospores and vegetative hyphae; reverse orange brown. DSA 34/25°C scattered knots of orange brown; reverse concolorous. PYE 14/25°C as on CER but darker orange; margin bright yellow.

**Notes:** This species slightly resembles *Gymnascella dankaliensis* but differs in having smaller ascospores which are proportionately thicker (pole to pole). The polar thickenings or bossae found in *Gymnascella dankaliensis* are lacking in *Gymnascella marginospora*. Colouration on artificial culture media and on natural substrata resembles *Arachniotus ruber* and *Gymnascella confluens*. Close examination of the ascospores is essential for accurate identification. Many workers consider *Gymnascella punctata* synonymous with this species, but its ascospore morphology and cultural characters are quite different. These are

discussed under that taxon. This is probably the most common and widespread species in the genus. It is found in soil, dung and other materials derived from animals.

**Material examined:** as *Arachniotus aureus* **ATCC** C. L. Shear/buzzard's stomach/Maryland; as *Arachniotus ruber* **ANSM** QM 1327/linen/?; **FH** BCI/?/Panama; as *Narasimhella hyalinospora* **UAMH** 3533 (=ATCC 15314)/buried cable/?; 3534 (=CBS 393.71)/soil/India; as *Pseudoarachniotus marginosporus* **NY** O-729/soil/Pennsylvania; NRRL 2850/?/Michigan; as *Rollandina capitata* **NY** O-112/soil/India; O-879/?/?; O-962/human/India; O-1083/?/India (neotype of *Rollandina capitata*); O-2509, -2542/soil/Panama; O-2591/marine sludge/Japan; O-3058/soil/Japan; O-3063/soil/Panama; O-3218/soil/Argentina; O-3333/soil/Italy; O-3450/?/? O-3589/soil/California; as *Rollandina hyalinospora* O-194/mouse dung/India; O-616, -963/bat dung/India; O-2055/tiger dung/California; O-3011/rabbit dung/India; O-3331/?/?; O-3428/?/?; **UAMH** 1902 from Orr as RSA 430 (1964).

*Gymnascella nodulosa* (Ghosh, Orr and Kuehn) comb. nov. .

FIG 5.14, PL 5.2c,d

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** O-735 (mouse dung, India). (O-735 also assigned to an isolate from guinea pig dung, India).

=*Petalosporus nodulosus* Ghosh, Orr and Kuehn, Mycopathol. et Mycol. Appl. **21**:36, 1963 (Basionym).

=*Petalosporus anodosus* Kuehn, Orr and Ghosh, Mycopathol. et Mycol. Appl. **23**:30, 1964.

**Ascomata:** golden yellow to golden brown, discrete, <1000*u*m, sometimes confluent. **Ascospores:** golden yellow, oblate, smooth, thick-walled, 2.1-2.3 x 3.8-5.2*u*m. **Asci:** petaloid ascospore clusters, to 12*u*m diam. **Peridial hyphae:** few to many golden yellow, irregularly thick-walled elements with swellings to 10-12*u*m diam., ±constrictions at septa, **Anamorph:** lacking. **In culture:** [UAMH 3161, 3162, 3769]. **PDA 25°C** At first white, glabrous to minutely pubescent becoming rather pasty, olive green and radiately sulcate; some white aerial mycelium with occasional yellow tufts indicating ascosporulation. Reverse pale

olive green after 30 days. On OAT pale yellow to pale brown granular patches of mycelium develop unevenly over the surface of the agar. [UAMH 3162]. CER 42/25°C brown to buff in centre, elsewhere pale cream-yellow, felty; reverse purple-brown to black. DSA 42/25°C scant hyaline growth; reverse uncolored. PYE 42/25°C tan to buff with yellow and olive shades; reverse olive-brown.

**Notes:** This taxon is considered by von Arx (1981) assignable to *Arachniotus citrinus* (here *G. citrina*). In fact, these two species are quite different. It is closest to *Gymnascella aurantiaca* but may be readily distinguished by the petaloid arrangement of the ascospores in the asci. Kuehn *et al.* (1964) described *Petalosporus anodosus* but did not satisfactorily distinguish the type from *Petalosporus nodulosus*. Representative strains of his new species displayed enough variation in culture to raise some doubts about the species concept he was using. In culture, the strains of each taxon are strikingly similar and there is no adequate basis for maintaining the two under separate names. The third species originally described in the genus *Petalosporus* has been assigned here to *Gymnascella afilamentosa*.

**Material examined:** as *Petalosporus anodosus*: **UAMH** 3161/fox dung/California; 3769/?/Arizona; as *Petalosporus nodulosus*: **UAMH** 1985; 3162 from Benjamin as RSA 1552.

*Gymnascella punctata* (Dutta and Ghosh) comb. nov. .

<u>FIG 5.15, PL 5.6d, 5.7b</u>

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** O-G-9 (rice paddy soil, India).

=*Pseudoarachniotus punctatus* Dutta and Ghosh, Mycologia **56**:153, 1964 (Basionym).

=*Arachniotus punctatus* (Dutta and Ghosh) von Arx, Persoonia **6**:373, 1971.

**Ascomata:** pale to bright pink becoming rusty orange, up to 250$um$ across when single; globose to very irregular, usually confluent in culture. **Ascospores:** brownish yellow, thick-walled, surface irregular and appearing punctate, 3.4-4.0 x 4.8-5.5$um$, with a very broad equatorial band approximately 1.5$um$ thick and representing approximately 1/3 of the spore width. **Asci:** ±globose, 10$um$

diam. **Peridial hyphae:** lacking or undifferentiated. **In culture:** [UAMH 3530]. **PDA 25°C** At first white, glabrous; becoming yellowish to pale orange in central area, elsewhere white, felty to granular; deep blue green diffusible pigment produced. Plate covered in 10 days. On OAT central area becomes densely felty, orange brown; reverse dark orange brown. CER 35/25°C pale orange, scant hyphae; reverse tinted yellow. DSA 49/25°C broad orange, granular halo; central region hyaline to pale yellow; reverse concolorous. PYE 49/25°C orange, felty, with white knots of overgrowth; reverse orange, tinted olive.

**Notes:** This species is quite distinct from *Gymnascella marginospora* which has similar ascospores, but a much more slender equatorial band and less irregular ascospore walls.

**Material examined: NY, RSA, UAMH** O-G-9 (=UAMH 3164 and 3530, =RSA 1544) (type strain as cited).

**GYMNOASCOIDEUS** Orr, Roy and Ghosh, 1977

Mycotaxon **5**:460.

**Type species:** *Gymnoascoideus petalosporus* Orr, Roy and Ghosh *op. cit.*

**Ascomata:** brown to greenish brown, discrete to confluent, globose, rarely greater than 1000*u*m diam. **Ascospores:** yellow to yellow-brown, oblate, smooth-walled, 1.4-3.5 x 3.5-4.9*u*m diam. **Asci:** ascospores disposed in a petaloid pattern, clusters ±globose to subglobose, to 10*u*m diam. **Peridial hyphae:** smooth-walled, anastomosed and branched at right angles, free apices blunt. **Anamorph:** arthroconidia.

**Notes:** Von Arx (1977) considered this taxon (as *"Gymnoascoides"*) intermediate between *Arachniotus* and *Gymnoascus* and placed the type species in the latter genus. The intermediate nature of the taxon is certainly supported by the nature of the peridium and morphology of the ascospores. However, the species lacks the distinctive peridial appendages characteristic of *Gymnoascus reessii*. The ascospores of *Gymnoascoideus petalosporus* have a flattened equator in contrast to the smooth tapering margin of the oblate ascospores of *Gymnoascus reessii*. Further, *Gymnoascus* lacks a anamorph whereas *G. petalosporus* produces numerous arthroconidia. The consistently well-developed,

regular, thick-walled peridial hyphae prevent considering this taxon in *Arachniotus*. or in *Gymnascella*.

*Gymnoascoideus petalosporus* Orr, Roy and Ghosh, 1977 Mycotaxon **5**:460-461

FIG 1-20.

FIG 5.16, PL 3.1a, 5.3b

**Type material:** HOLOTYPE (*cultura desiccata*). **NY** O-3325 (nodular cyst of human, India). ≡*Gymnoascus petalosporus* (Orr, Roy and Ghosh) von Arx, Persoonia **9**:387 1977.

**Ascomata:** brown to greenish brown, discrete to confluent, globose, 150-750*um* diam. **Ascospores:** yellow to yellow-brown, smooth, thick-walled, oblate, 1.3-3.3 x 2.6-4.9*um* diam. **Asci:** globose to subglobose, 8.4-10*um* diam. **Peridial hyphae:** hyaline or very pale buff, smooth, thick-walled, anastomosed and branched at right angles, free apices blunt, 2.5-4.5*um*. **Anamorph:** arthroconidia numerous, thick-walled, finely verrucose, hyaline, buff or pale brown, irregular in size, 1.4-4.0 x 2.0-5.5*um*. **In culture:** [UAMH 1665, 1712, 3525, 3592, 3593, 3656, 3704, 3766, 3908]. **PDA 25°C** At first hyaline soon becoming pale orange, cottony. reverse yellow. Becoming tan, granular with development of ascospores, zonate. reverse yellow-brown becoming red brown and finally dark brown at 30 days. On OAT, mycelium is tan and granular in patches. Plate covered in 10 to 15 days. [UAMH 1665]. CER 14/25°C scattered patches of buff to cream brown, felty mycelium; reverse bright yellow. DSA 35/25°C scattered white knots of hyphae, reverse uncolored. PYE 14/25°C thick, felty mat of cream to buff brown mycelium; reverse bright yellow-brown.

**Notes:** Found most frequently in soil and materials of animal origin (mostly other than dung).

**Material examined:** **UAMH** 1665 (type strain as cited) **FH, UAMH 1665** from Orr as BOSE 503 (1963) as type strain. O-288c (=UAMH 1777)/soil/Guatemala; O-1163 (=UAMH 3704, 3831)/rat dung/India; O-1177 (=UAMH 3525)/horn/India; O-1321 (=UAMH 3908)/soil/Italy; O-1505 (=UAMH 3592)/horse ringworm/Utah; O-2013 (=UAMH 3798)/soil/India; O-3212 (=UAMH 3766)/sputum/Kansas;

O-3352 (=UAMH 1712)/soil/Guatemala; O-3473 (=UAMH 3656)/horse ringworm/Utah; O-3552 (=UAMH 3593)/foot lesion/Utah; O-3640 (=UAMH 3591)/contaminant/Utah; **UAMH** 3478/soil/Chile; 4152/beach sand/Italy; 4153, 4154/flower bed soil/Italy. **NY** O-1177/horn/India; O-1239/soil on horn/India; O-1299/pigeon feathers/Yugoslavia; O-2013/soil/India; O-2060/rodent/Arizona; O-2067/human lesion/California; O-3324/soil/Panama; O-3341, -3359/soil/Italy; O-3442/soil/England; O-3454/duck feathers/Queensland; O-3629/soil/California; O-3719/soil/Italy.

**GYMNOASCUS** Baranetzky, 1872

Botanische Zeitung **30**:158.

**Type species:** *Gymnoascus reessii* Baranetzky *op. cit.*

**Ascomata:** variable in color - pale yellow to brick-red or brown, sometimes green tinged, roughly globose, and often confluent, individual ascomata generally <1000*um*. **Ascospores:** pale yellow, smooth, oblate, rim acute rather than flattened, approx. 4.5*um* diam. **Asci:** ±globose, evanescent, 8-spored. **Peridial hyphae:** usually yellow to reddish brown, septate, thick-walled, conspicuously roughened. **Appendages:** when present, colored same as peridial hyphae, septate, thick-walled, coarsely roughened, branched. **Thallism:** homothallic. **Anamorph:** lacking.

**Notes:** Orr recognized 5 species in 1977, including with the type: *G. dugwayensis, G. longitrichus, G. intermedius* and *G. uncinatus*. The latter species is here considered a species of *Uncinocarpus* (Onygenaceae) in recognition of its keratinolytic capacities, punctate ascospores and arthroconidial anamorph. The first two species, distinguished on the basis of appendage characteristics, are within the range of variability of *Gymnoascus reessii* and are considered here as facultative synonyms of that species. *Gymnoascus intermedius* is discussed below. In his concept of *Gymnoascus*, Von Arx (1981a) included *Gymnoascus*, *Gymnascella*, *Gymnoascoideus* (as "*Gymnoascoides*"), *Macronodus* (as *Gymnoascus bifurcatus*), *Neogymnomyces*, *Pectinotrichum* and *Uncinocarpus*. Since his treatment of the genus lacks discussion it is not possible to begin to explain why such a broad generic concept was applied.

**References:** Apinis, 1964 (broad concept includes *Pseudogymnoascus, Auxarthron,* and *Gymnoascus*; a key to species is provided). Dale, 1903 (life history and developmental study of *Gymnoascus reessii*); Kuehn, 1956 (developmental morphology).

*Gymnoascus intermedius* Orr 1977 Mycotaxon **5**:470-472, FIG 1-6.

FIG 5.17, PL 5.1d,e,f

**Type material:** HOLOTYPE (*cultura desiccata*). **NY** O-313 (soil, California).

**Ascomata:** yellow or yellow-green, ±globose, 75-470*um*, mostly confluent, but sometimes discrete. **Ascospores:** yellow, smooth, oblate, 1.9-3.0 x 4.0-5.0*um*. **Asci:** hyaline, ellipsoidal, 5.7-6.0 x 6.0-8.6*um*. **Peridial hyphae:** smooth, straight, branched at right angles, anastomosing, 1.9-3.4*um*, occasionally some elements swollen to 6*um*. **In culture:** no cultures examined.

**Material examined:** as *Arachniotus lanatus*: **TRTC** 45468/dwelling/Ontario; as *Arachniotus* sp.: **RSA** 1443/lizard dung/Mexico; as *Gymnoascus intermedius* **FH, NY** O-104; O-291/soil/California; O-313/soil/California (type strain).

**Notes:** This species may be distinguished from *Gymnoascoideus petalosporus* by the absence of arthroconidia.

*Gymnoascus reessii* Baranetzky, 1872 Botanische Zeitung **30**:158 Taf IIIA FIG 1-26.

FIG 5.18, PL 3.16, 3.8d

**Type material:** none.

=*Myxotrichum ochraceum* Berkeley and Broome, Grevillea **3**:184 (see Massee and Salmon, 1902).

=*Myxotrichum coprogenum* Saccardo, Michelia 2:372, 1881, (see Massee and Salmon, 1902).

=*Gymnoascus dugwayensis* Orr and Kuehn, Mycologia **64**:65, 1972.

=*Gymnoascus longitrichus* Orr and Kuehn *apud* Orr, Kuehn and Plunkett, Mycopathol. et Mycol. Appl. **21**:9, 1963.

=*Gymnoascus corniculatus* Orr and Plunkett *apud* Orr *et al., op. cit.*

**Ascomata:** yellow, red-brown or orange-brown, globose, confluent, 50-600*um* diam incl. appendages. **Ascospores:** yellow to reddish brown, smooth, 1.4-2.4

x 3.2-4$\mu$m, oblate. **Asci:** subspherical to ovoid, 7.7-13$\mu$m diam. **Peridial hyphae:** red, yellow, green, brown, thick-walled, cuticularized, 2.2-4.4$\mu$m diam., smooth, or asperulate to coarsely rugose. **Appendages:** branched or unbranched. branches short, curved, blunt to subacute, apex hooked or bent, unequally bifurcate, curved "boat hooks" or trifurcate in "antlers." Some isolates with very long appendages to 500$\mu$m in length. **In culture:** [UAMH 1604]. CER 35/25°C ochre-yellow to olive green mounds on pinkish tan smooth mycelium; reverse yellow-brown. DSA 32/25°C orange-brown, discrete knots scant; reverse hyaline or concolorous. PYE 21/25°C brownish yellow to cream with greenish tinge in central area; reverse yellowish green.

**Notes:** This largely coprophilous species is extremely common, especially on herbivore dung (horse, rabbit and sheep), and displays a wide range of variability in color and morphology of the peridial hyphae and appendages (Orr, Kuehn and Plunkett, 1963d). It is cosmopolitan in distribution and in addition to its coprophilous habit it has been found in soils of various types (see Domsch, Gams and Anderson (1980)) as well as in decaying vegetable matter (Udagawa, 1963). Additional detailed descriptions can be found in Benjamin (1956), and Domsch, Gams and Anderson (1980).

**Material examined:** as *Gymnoascus corniculatus*: **RSA** 1548/substrate?/California; **TRTC** C1623/porcupine dung/Ontario; **UAMH** 3159 (=RSA 1549)/soil/California; as *Gymnoascus reessii*: **BP** 53884, 53885/deer dung/Hungary; **DAOM** 124076/rat dung/Kansas; **E** Watling 8182/cat dung/Scotland; 1200/lab contaminant/Scotland; ?/toilet/Scotland; **FH** O-146 (=UAMH 1606) (Not typical); O-217; **NY** rat dung/? (*Gymnoascus coprogenum*); as *Gymnoascus reessii*: **RSA** 404/coyote dung/California; 61/rat dung/Massachusetts; 1259/lizard dung/California; 2506/mouse dung/California; 201/dung/California; **S** G; Winter/sheep dung/Germany?; **TRTC** 66;1738j/elephant dung/Tanzania; 66.3276/elephant dung/Kenya; 6511/finch dung/Germany; 6844/fowl dung/India; 6521/roe dung/Germany; 34654/fox dung/Ontario; 12187/goose dung/Quebec; (FH, NY) 6509/hare dung/Germany; 6842/rat dung/India; 17870/antelope dung/Tanzania CBS-Clausen; 32269/porcupine dung/Wyoming; 66.1440/herbivore dung/Kenya;

66.3111/herbivore dung/Tanzania; **UAMH** 1604/pack rat dung/California from Orr as O-146 (1960); 3140 (=RSA 1485)/lizard Dung/Mexico; 2488/hand scraping/Alberta; UAMH 4809/coyote dung/Alberta, coll; Currah; **UPS** Santesson 12350/roe dung/Sweden; as *Gymnoascus ruber*: **MICH** Povah 177/dung/Michigan; **NY** O-146; O-2605/clay soil/Utah; Martin 6466/deer dung/California; Rogerson 36-1/dung/Utah; **DAOM** 122144 (=Thaxter 1925)/dog dung; **FH** ?/dog dung/Argentina (with *Arachniotus ruber*); as *Gymnoascus zuffianus*: **UPS** Lundqvist 5647-r/sheep dung/Libya; as *Myxotrichum coprogenum*: **BR** Bommer and Rousseau/mouse dung/France.

## SPECIES EXCLUDED OR REFERRED TO OTHER GENERA

*Gymnoascus aurantiacus* (Peck) Saccardo, Sylloge Fungorum **8**:823
  ≡*Gymnascella aurantiaca*.

*Gymnoascus brevisetosus* Kuehn, Mycologia **48**:813, 1956
  =*Auxarthron zuffianum* (Onygenaceae).

*Gymnoascus californiensis* (Orr and Kuehn) Apinis, Mycol. Pap. **96**:12, 1964
  ≡*Auxarthron californiense* (Onygenaceae).

*Gymnoascus confluens* Sartory and Bainier, Bull. Soc. Mycol. Fr. **29**:261, 1913
  ≡*Gymnascella confluens*

*Gymnoascus corniculatus* Orr and Plunkett, Mycopathol. et Mycol. Appl. **21**:1, 1963
  =*Gymnoascus reessii*

*Gymnoascus demonbreunii* Ajello and Cheng, Mycologia **59**:682, 1967
  ≡*Neogymnomyces demonbreunii* (Onygenaceae).

*Gymnoascus dugwayensis* Orr and Kuehn
  =*Gymnoascus reessii*.

*Gymnoascus durus* Zukal, Ber. dtsch. bot. Ges. **8**:259, 1890
  ≡*Keratinophyton durum* (Onygenaceae).

*Gymnoascus eidami* Cocconi, Mem. R. Acad. Sci. Bologna V 2: 32, 1891
  =*Auxarthron zuffianum* (Morini) Orr and Kuehn *fide* Orr and Kuehn and Plunkett, 1963.

*Gymnoascus flavus* Klocker, Nova Hedwigia **41**:80, 1902.

=*Talaromyces flavus* var. *flavus* Stolk and Samson, CBS Stud. Mycol. **2**:11, 1972 (Eurotiales).

*Gymnoascus gypseus* Nannizzi, Atti. R. Acad. Fis. Siena 2: 94, 1927
=*Nannizzia gypsea* (Arthrodermataceae).

*Gymnoascus johnstoni* (Massee and Salmon) Orr and Kuehn, Mycopathol. et Mycol. Appl. **21**:8, 1963
( *Species incertis est.*)

*Gymnoascus longitrichus* Orr and Kuehn
=*Gymnoascus reessii*.

*Gymnoascus luteus* Saccardo, Sylloge Fungorum **11**:437, 1895 =*Talaromyces luteus* (Saccardo) Stolk and Samson 1972 (Eurotiales).

*Gymnoascus myriosporus* Rostrup, Med. om Groenland **18**:12, 1894.
=*Myrillium myriosporus* (Rostrup) Clements
see Clements and Shear, 1931.

*Gymnoascus ossicola* Rostrup, Bot. Tidsk. **21**:45, 1897
=*Nannizzia ossicola* (Arthrodermataceae).

*Gymnoascus petalosporus* (Orr, Roy and Ghosh) Von Arx, 1977
=*Gymnoascoideus petalosporus*.

*Gymnoascus racovitzae* Lagarde Arch. Zool. exp. gen. **53**:281, 1913
=*Kuehniella racovitzae* (Onygenaceae).

*Gymnoascus reticulatus* Zukal Verh. Zool.-Bot. Ges. Wien **37**:40, 1887
=*Auxarthron reticulatum* (Onygenaceae).

*Gymnoascus rhousiogongylinus* Wener and Cain, Can. J. Bot. **48**:325, 1970
=*Pseudogymnoascus roseus* (Myxotrichaceae).

*Gymnoascus ruber* Van Tieghem, Bull. Soc. Bot. Fr. **24**:159, 1877
=*Arachniotus ruber*.

*Gymnoascus setosus* Eidam, Bot. Cent. **10** :107, 1882
=*Myxotrichum setosum* (Myxotrichaceae).

*Gymnoascus siglerae* von Arx The Genera of Fungi Sporulating in Pure Culture Von Arx, 3rd Edition. p132
=*Uncinocarpus reesii* (Onygenaceae).

*Gymnoascus stipitatus* Lindfors, Svensk. Bot. Tidskr. **14**:270, 1920

=*Myxotrichum stipitatum* (Myxotrichaceae).

*Gymnoascus subumbrinus* Smith, Trans. Brit. mycol. Soc. **5**:424, 1917

=*Auxarthron umbrinum* (Onygenaceae).

*Gymnoascus sudans* Valionis, Vyt. Didziojo Mat. Gamtos Fak. Darbei **11**:115, 1936

=*Byssochlamys nivea* Westling (Eurotiales, See Stolk and Samson, 1971).

*Gymnoascus umbrinus* Boudier, Bull. Soc. Mycol. Fr. **8**:43, 1892

=*Auxarthron umbrinum* (Onygenaceae).

*Gymnoascus verrucosus* Eidam, Jber. Schles. Ges. vaterl. Kult. **64**:162, 1887

=*Amauroascus mutatus* (Onygenaceae).

*Gymnoascus verticillatus* A. L. Smith, Trans. Brit. mycol. Soc. **1**:154, 1896

see discussion on *Oncocladium flavum* (Onygenaceae).

*Gymnoascus vinaceus* (Raillo) Apinis, Mycol. Pap. **96**:9, 1964

=*Pseudogymnoascus roseus* (Myxotrichaceae).

*Gymnoascus zuffianus* Morini, Mem. R. Acad. Sci. Bolgna V **2**:32, 1891

=*Auxarthron zuffianum* (Onygenaceae).

Figure 5.1. *Acitheca purpurea* (FH, Holotype).

a Globose ascoma (reticuloperidium) of thick-walled, interwoven peridial hyphae. X600.

b Smooth-walled, oblate ascospores. X5500.

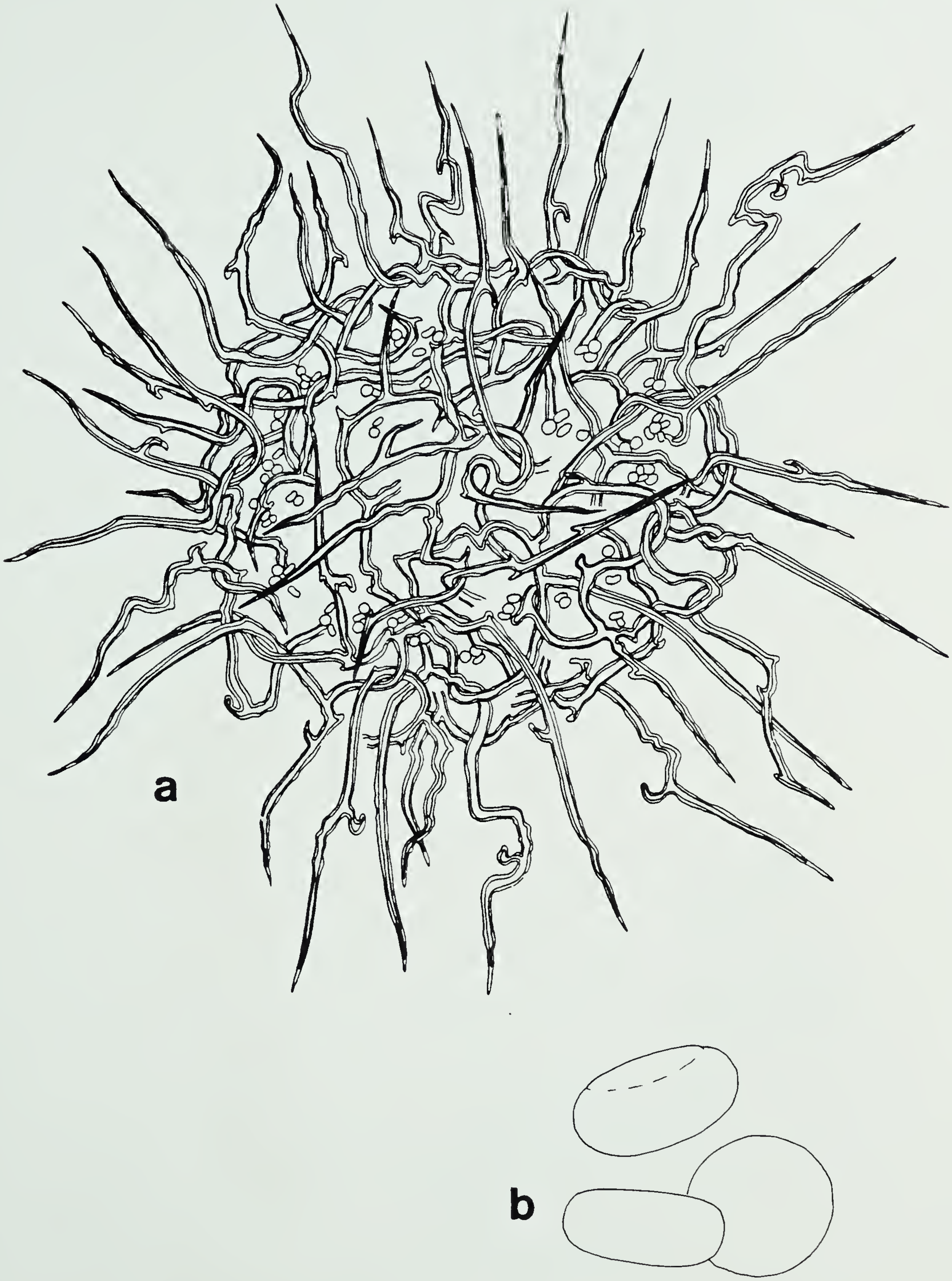

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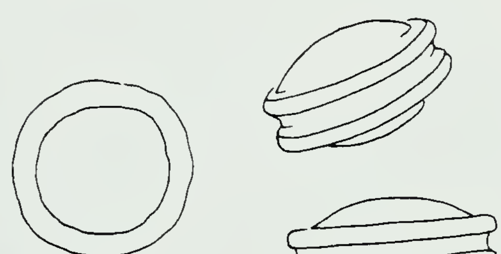
Figure 5.2. *Arachniotus ruber* (UAMH 4763).

**a** A discrete ascoma with a telaperidium. X1210.

**b** Pulley-wheel shaped ascospores. X3900.

**c** Conglobate ascospores. X3900.

a



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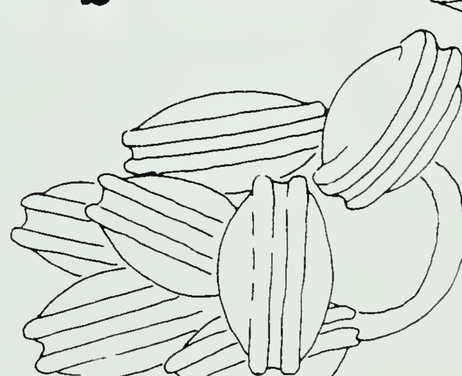

c

Figure 5.3. *Arachniotus ruber* (UAMH 3543).

a Thin-walled, ±inflated peridial hyphae. X1000.

b Pulley-wheel shaped ascospores with equatorial grooves bordered by distinctly thickened walls. X7000.

c Globose ascus with closely packed ascospores. X7000.

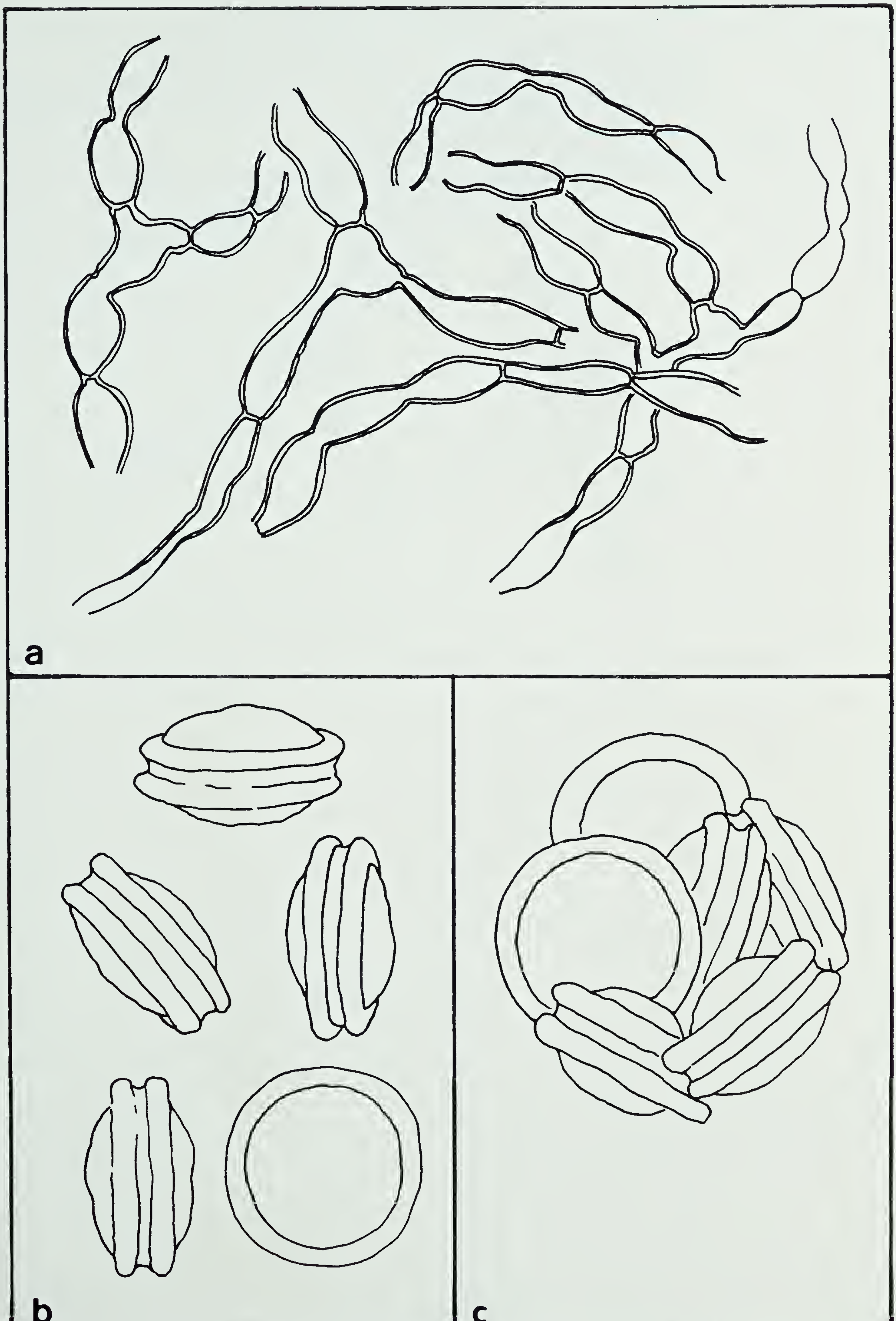
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Figure 5.4. *Gymnascella afilamentosa* (NY 0-3345).

**a** Several slightly thick-walled peridial hyphae. X2000.

**b** Smooth-walled, oblate ascospores with characteristic wall thickenings based in shallow polar depressions. X5000.

**c** Petaloid arrangement of conglobate ascospores. X4800.

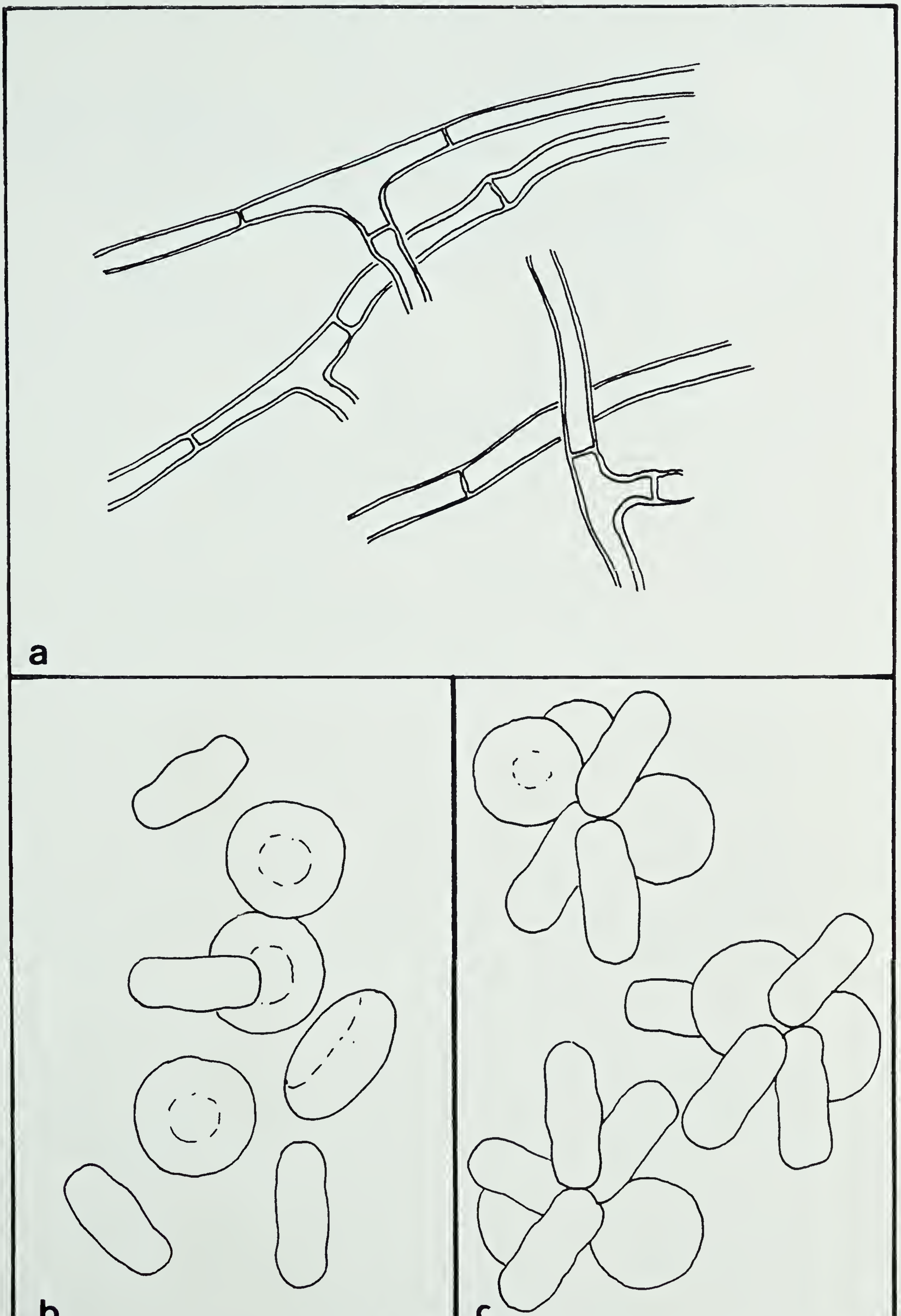
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Figure 5.5. *Gymnascella aurantiaca* (U 178821).

**a** Thick-walled peridial elements. X2500.

**b** Ascospores showing variation in polar faces: some with slight boss-like thickenings, and others with shallow polar depressions. X5000.

**c** Characteristic ±globose asci showing compact arrangement of ascospores. X4545.

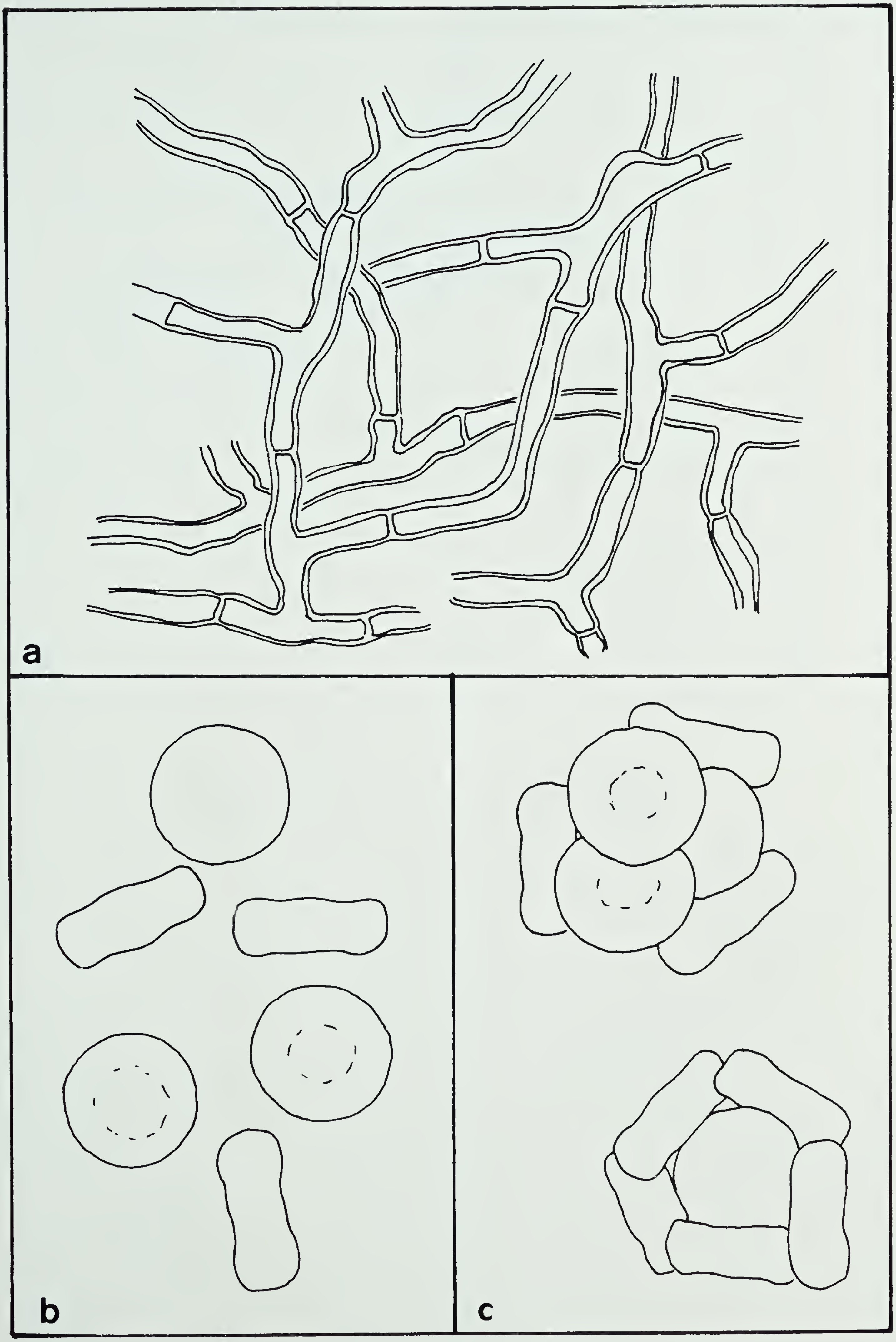
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Figure 5.6 *Gymnascella (?)candida* (K Sydow 4031).

a Regular, thin-walled hyphae of the peridium. X1000.

b *Arthrographis cuboidea*? redrawn from Dale (1903) Plate 28, figures 56 and 57.

c Oblate, smooth, thick-walled ascospores with boss-like polar thickenings and flattened equatorial zones. X5000.

d Asci showing closely packed ascospores. X4025.

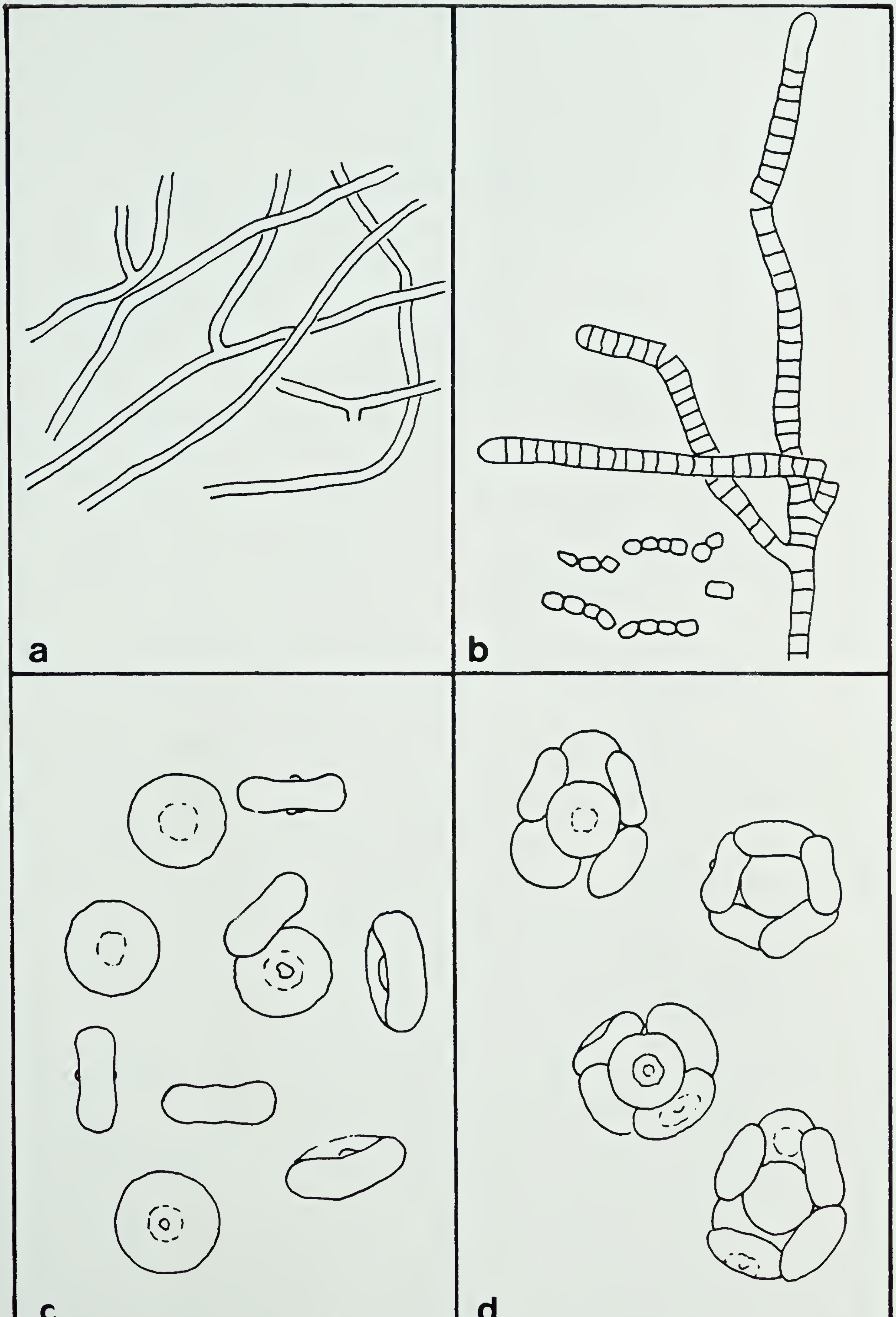
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Figure 5.7. *Gymnascella citrina* (UAMH 3545).

**a** Regular, thin-walled peridial hyphae. X1335.

**b** Smooth, thick-walled, ±oblate ascospores showing characteristic rhomboidal shape in side view X5400.

**c** Closely packed ascospores in ±globose asci. X5400.

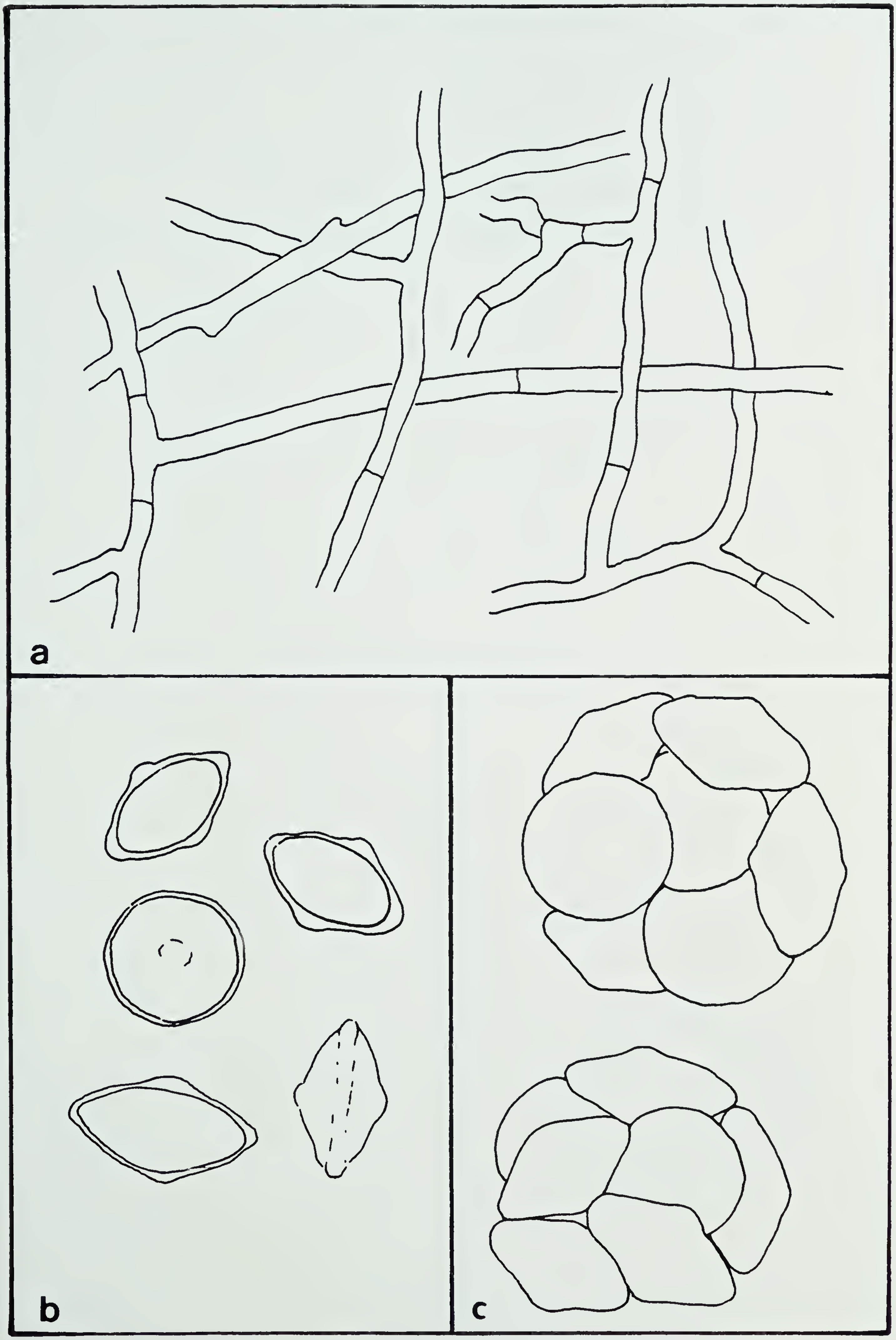
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Figure 5.8. *Gymnascella confluens* (RSA 1240).

**a** Thin-walled, slightly irregular hyphae which comprise the bulk of the peridium. X1330.

**b** Smooth, thick-walled, oblate ascospores with ±flattened poles and broad, shallow equatorial depressions. X5280.

**c** Closely packed ascospores in globose or ovoid asci. X3900.

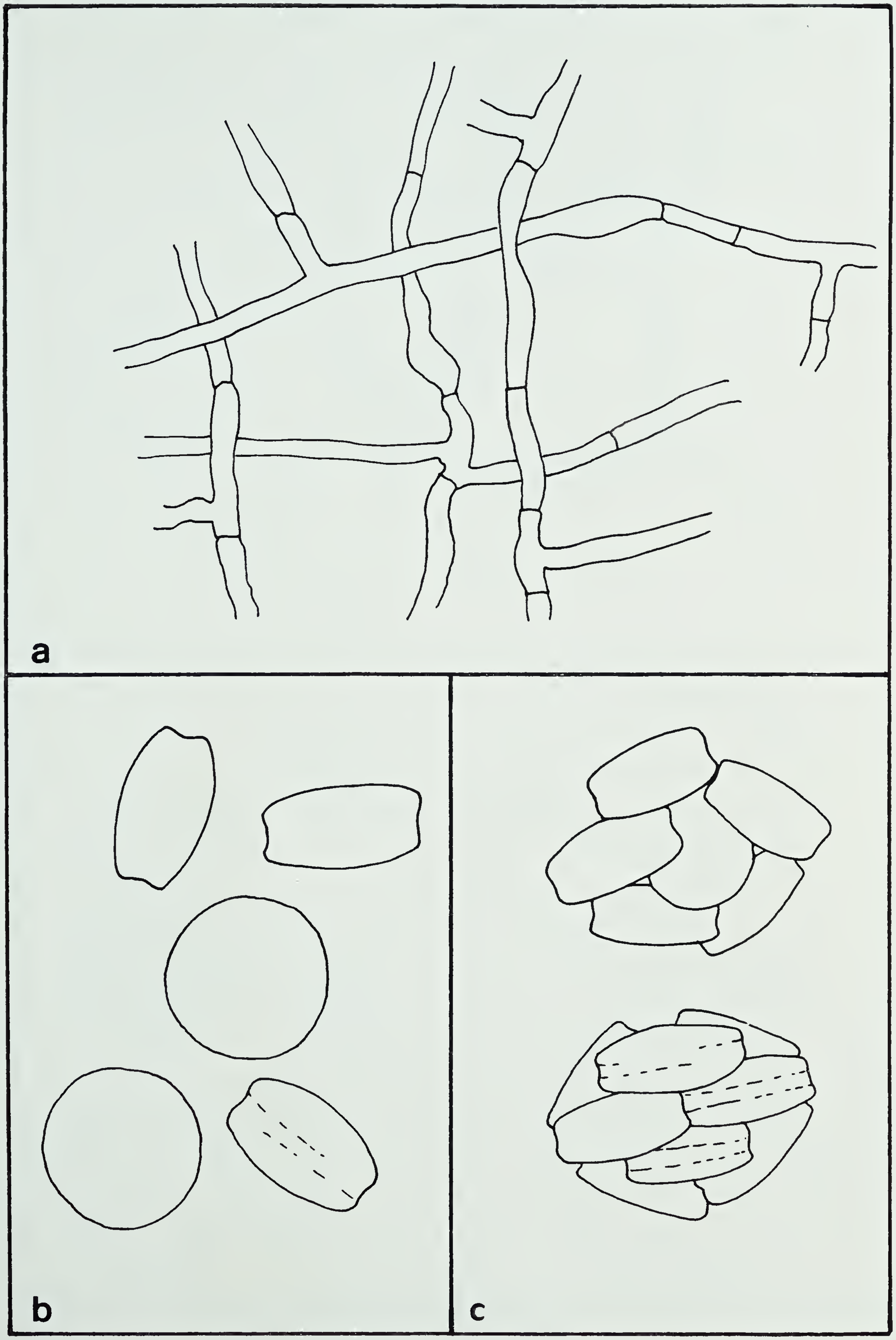
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Figure 5.9. *Gymnascella dankaliensis* (NY O-902).

**a** Gnarled, ±thick-walled, roughened hyphae of the peridium. X1400.

**b** Oblate ascospores with polar and equatorial thickenings and characteristic irregular exterior wall surfaces. X4285.

**c** Asci containing closely packed ascospores. X4910.

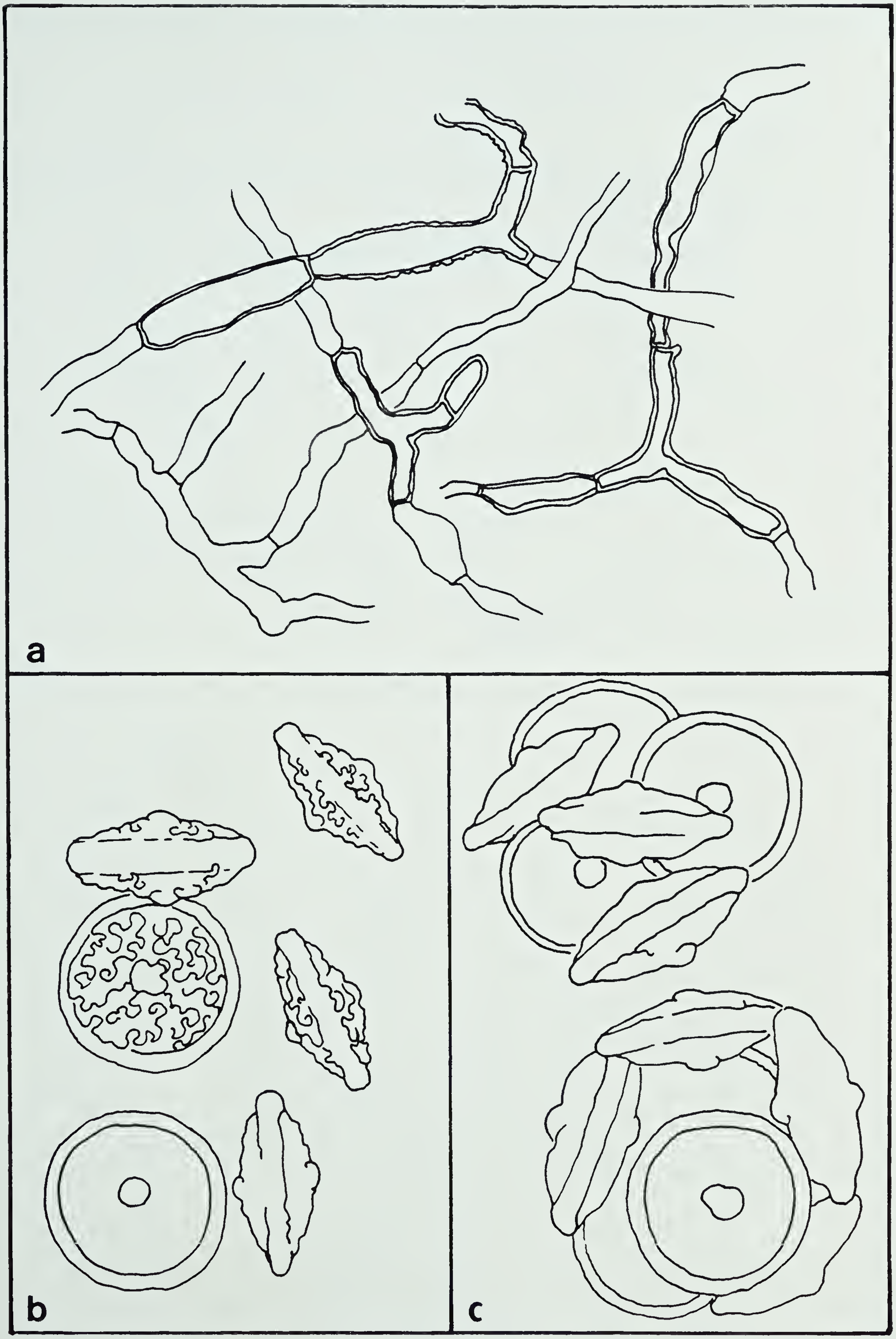
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Figure 5.10. *Gymnascella devroeyi* (RSA 1481).

**a** Short, irregular, disarticulated, thick-walled elements of the peridium. X2365.

**b** Smooth, thick-walled, broad, oblate ascospores with ±flattened poles and equators. X5000.

**c** Ascospores closely packed in a ±globose ascus. X4285.

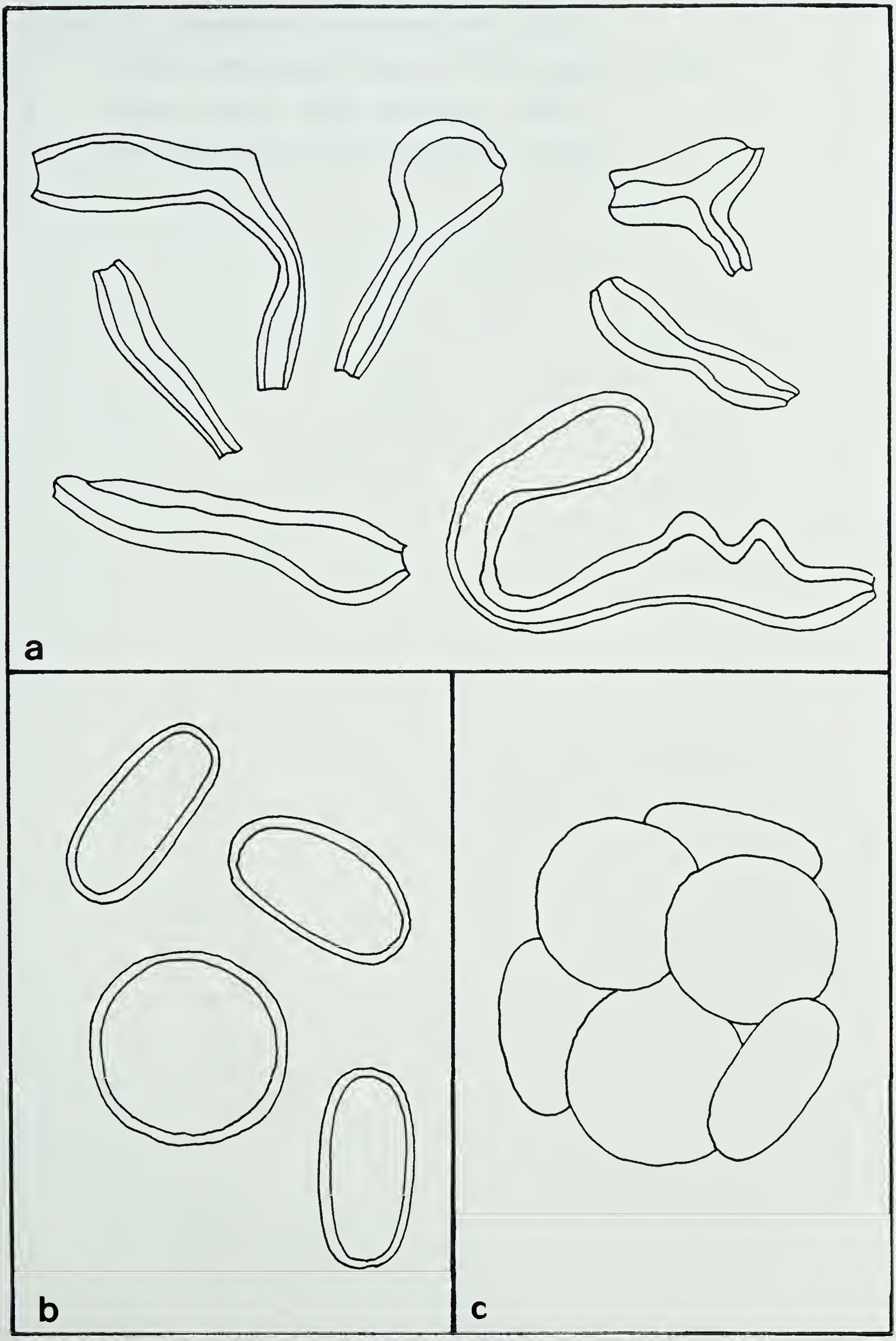
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Figure 5.11. *Gymnascella hyalinospora* (RSA 1529).

a Typical undifferentiated hyphae of the peridium. X1000.

b Sparsely warted, oblate ascospores. X6665.

c Asci with closely packed ascospores. X4285.

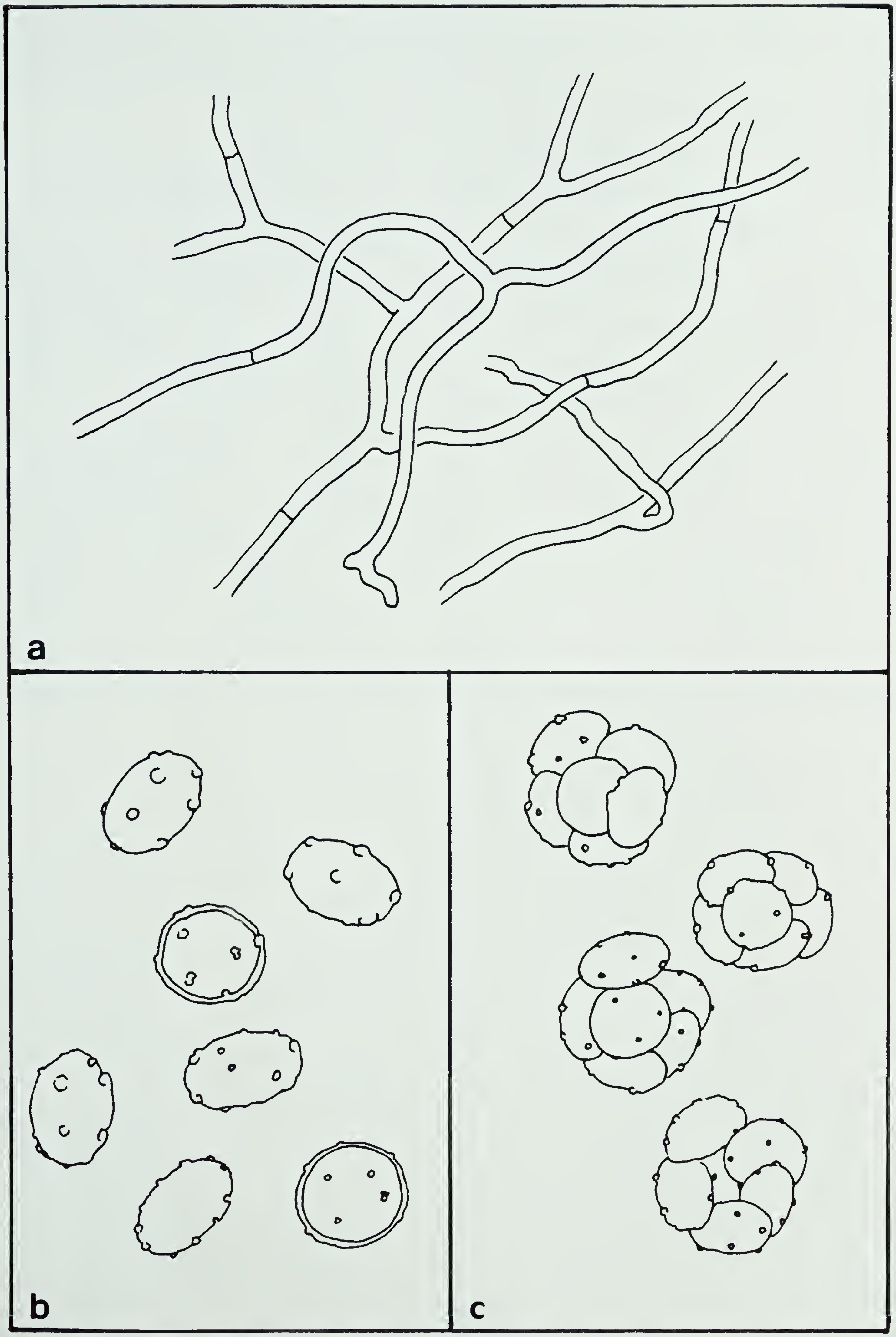
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Figure 5.12. *Gymnascella littoralis* (NY O-3053).

**a** Smooth, ±irregular, somewhat thick-walled hyphae of the peridium showing slightly swollen, blunt ends. X1670.

**b** Smooth, thick-walled arthroconidia. X3500.

**c** Broadly oblate ascospores with flattened poles and equatorial thickenings. X7045.

**d** Closely packed ascospores in characteristic ±globose asci. X4000.

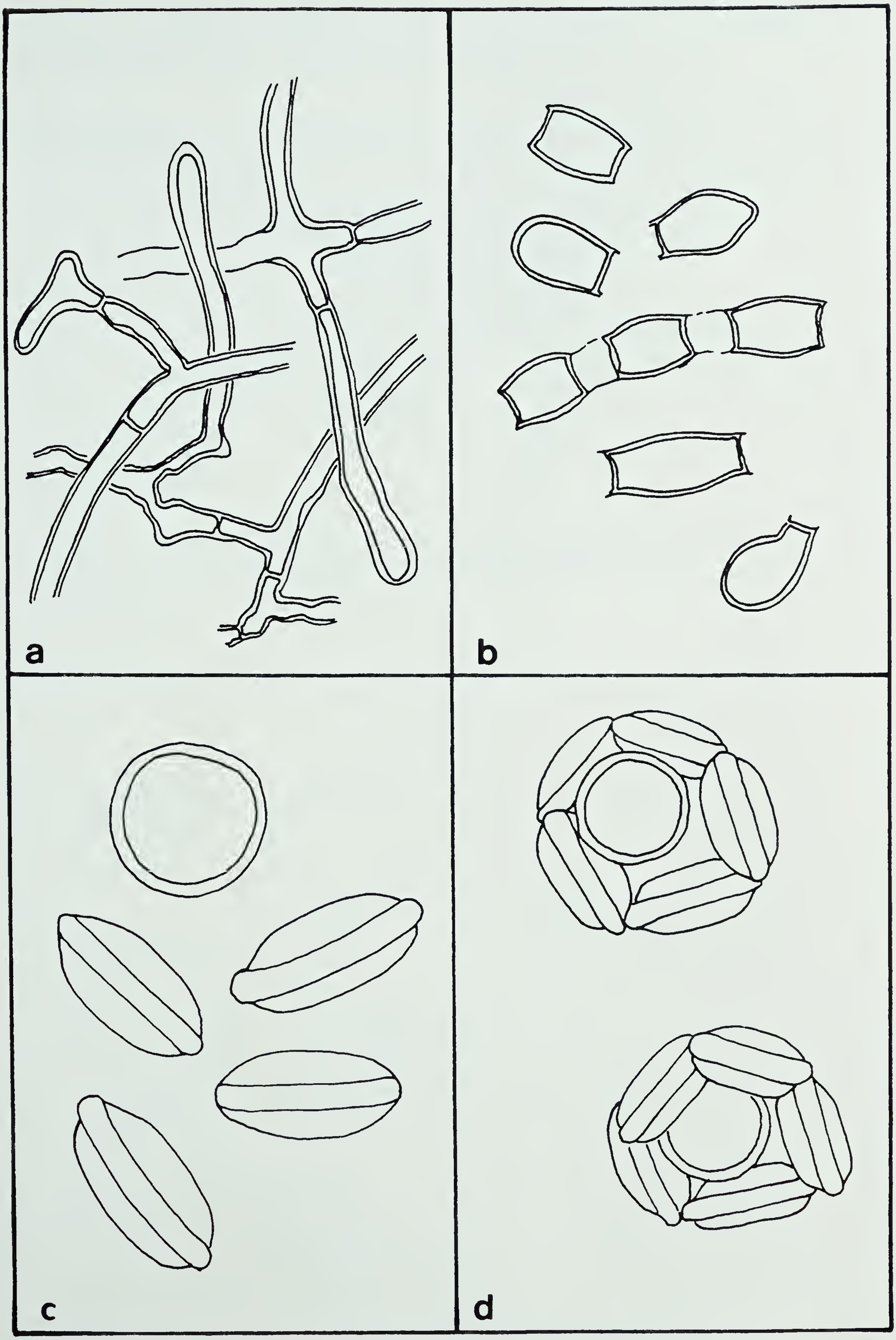
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Figure 5.13. *Gymnascella marginospora* (ANSM QM 1327).

**a** Atypical peridial hyphae showing smooth, thick-walled elements of irregular diameter. X1500.

**b** Ascospores with irregular wall surface and prominent equatorial band. X7140.

**c** Closely packed ascospores in ±globose asci. X7000.

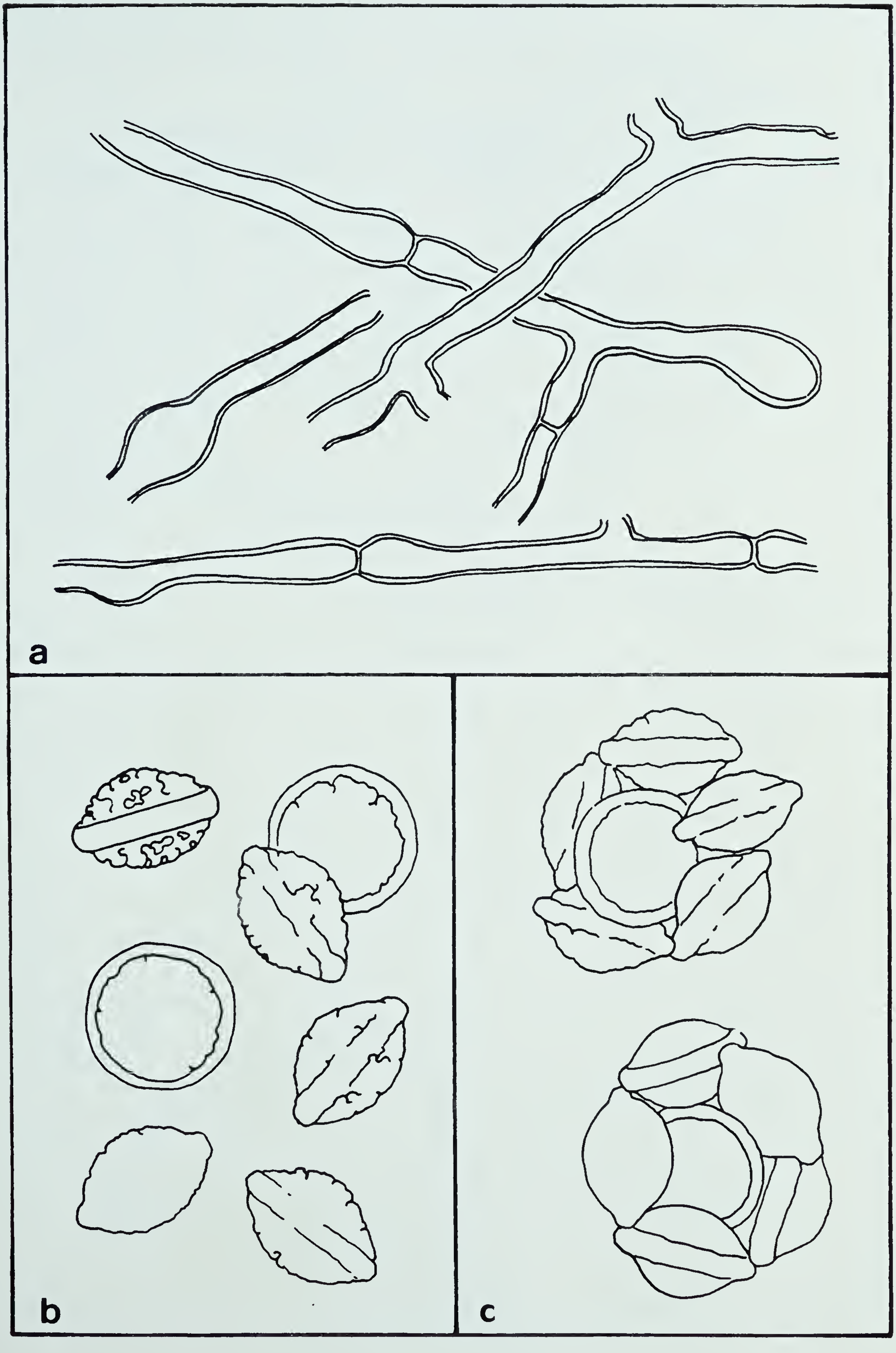
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Figure 5.14. *Gymnascella nodulosa* (UAMH 3162).

**a** Irregularly thick-walled elements showing swellings and constrictions at septa. X2200.

**b** Smooth, oblate ascospores with flattened rims. X6875.

**c** Asci containing ascospores in characteristic petaloid arrangement. X7500.

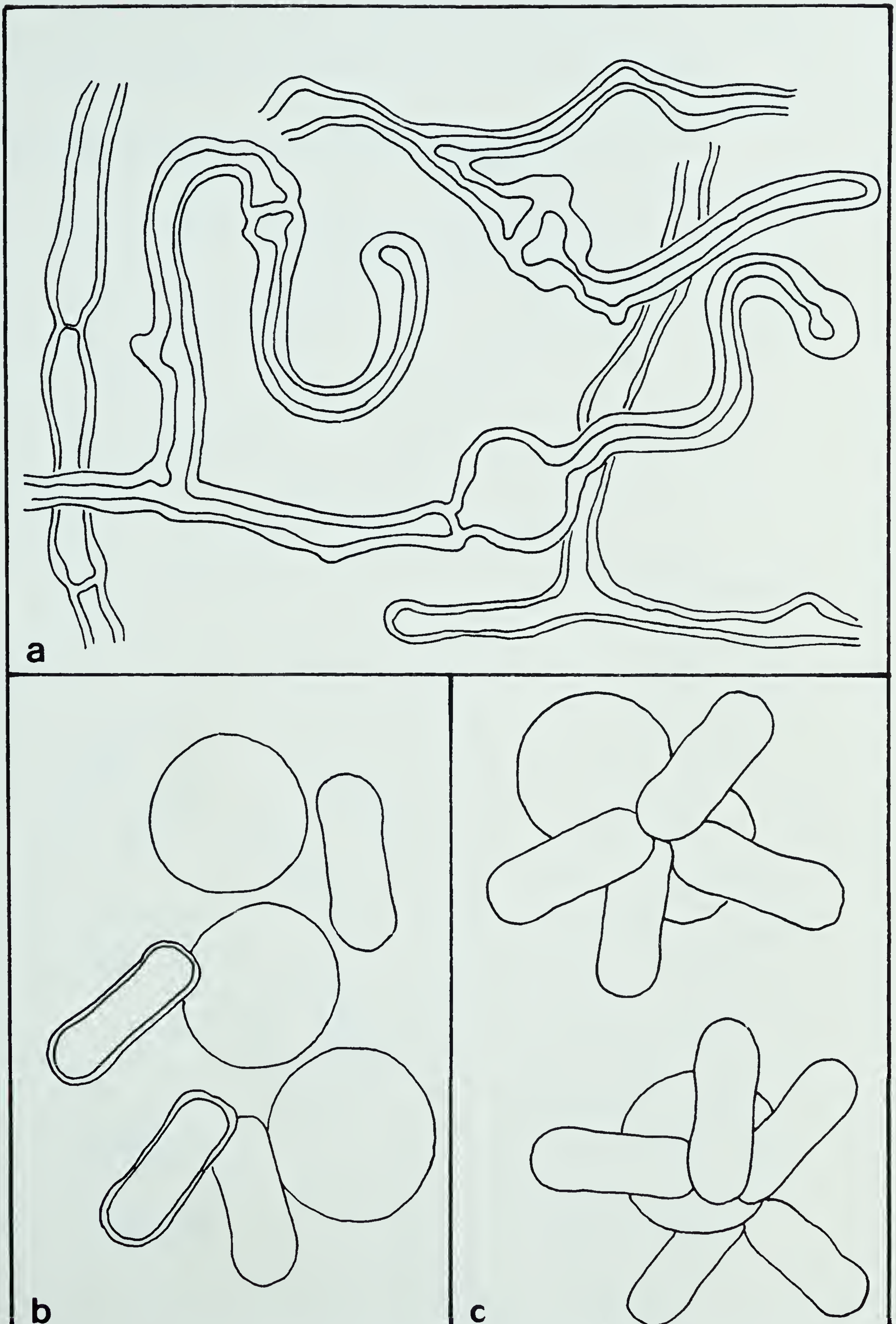

Figure 5.15. *Gymnascella punctata* (UAMH 1544).

**a** Regular peridial hyphae undifferentiated from vegetative hyphae. X1000.

**b** Ascospores with irregularly convoluted walls and broad equatorial margin. X3845.

**c** Asci showing closely packed ascospores. X5100.

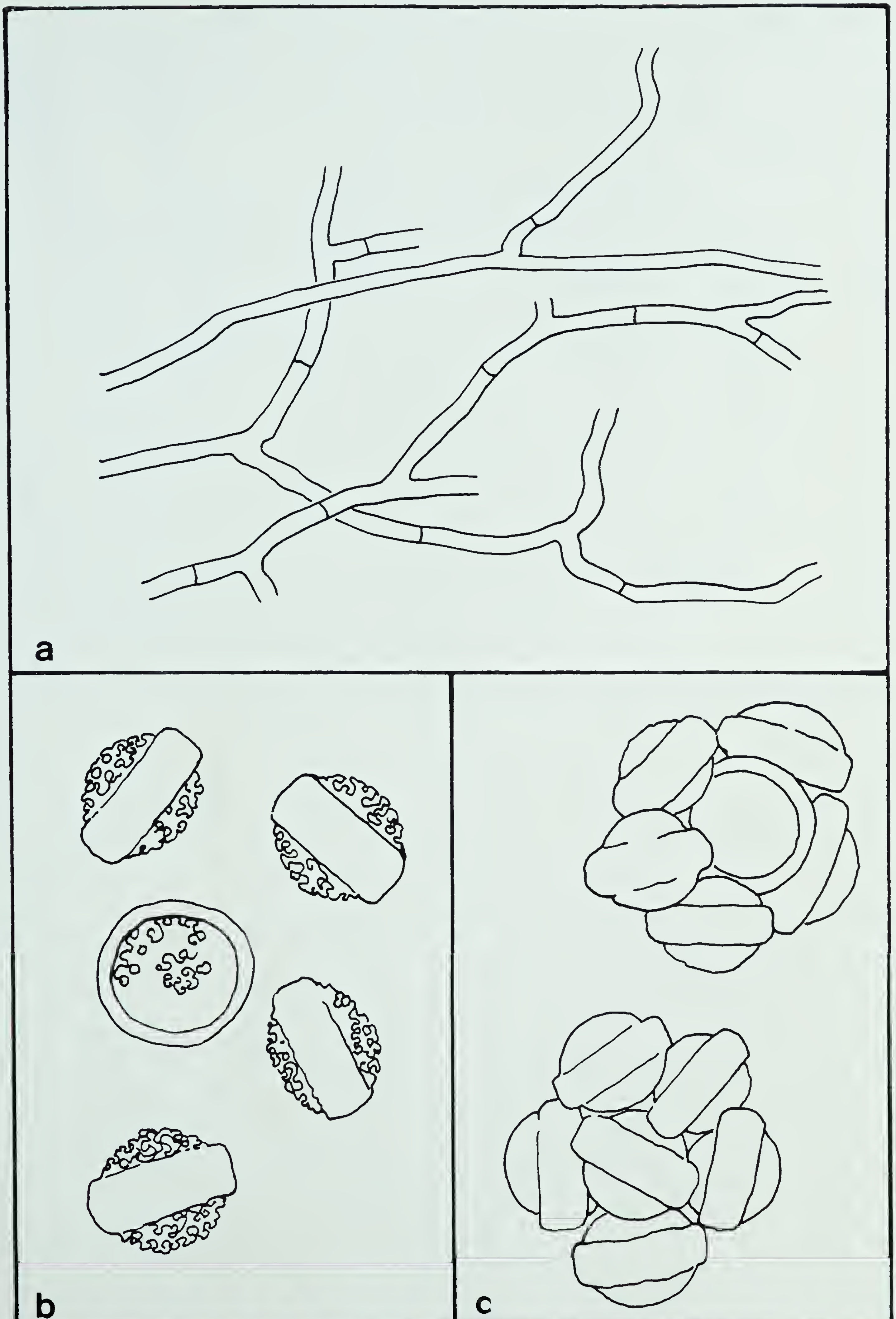
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Figure 5.16. *Gymnascoideus petalosporus* (UAMH 1665).

**a** Thick-walled peridial hyphae; some areas irregular in width.. X1820.

**b** Thick-walled, finely roughened arthroconidia of *Malbranchea* anamorph. X2000.

**c** Smooth, thick-walled, oblate ascospores. X8125.

**d** Asci showing petaloid arrangement of ascospores. X7810.

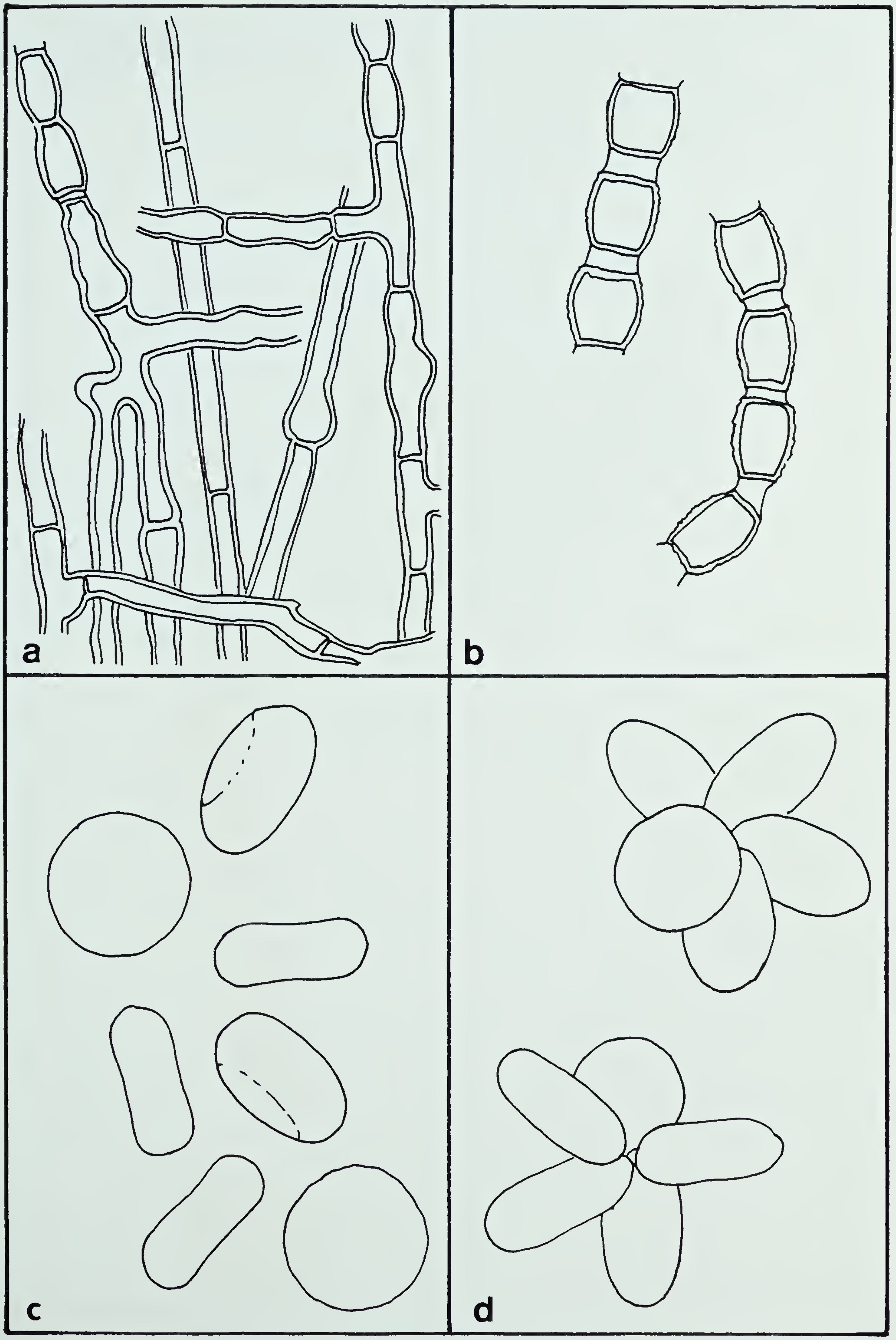
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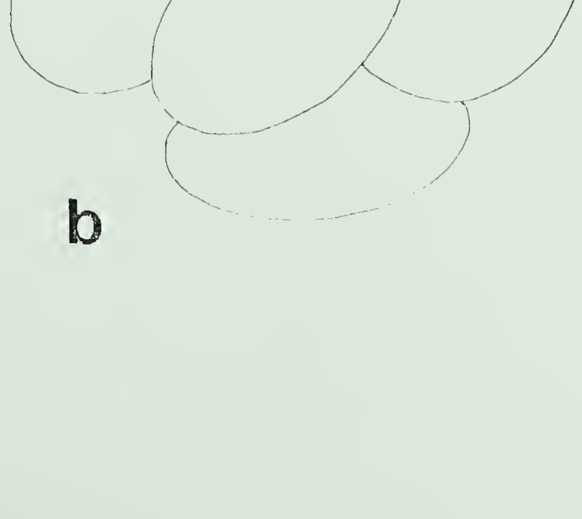
Figure 5.17. *Gymnoascus intermedius* (NY O-313).

**a** Section of confluent ascomatal mass, showing right-angle branching of thick-walled peridial elements. X925.

**b** Smooth, conglobate, oblate ascospores. X8120.

a



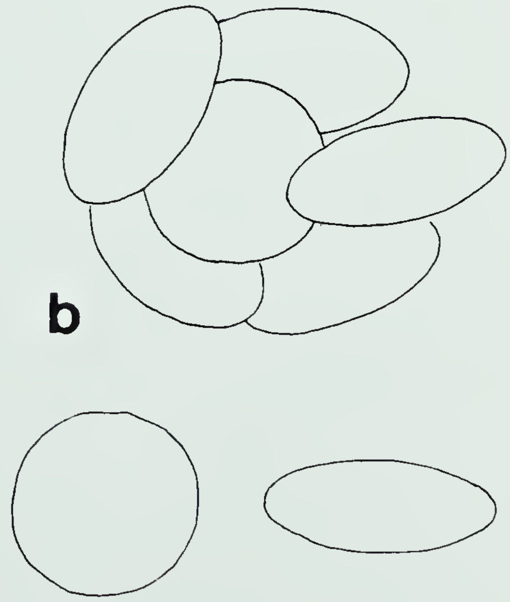
b

Figure 5.18. *Gymnoascus reessii* (Ground squirrel dung, southern Alberta, Uncatalogued).

**a** Ascoma showing distinctive arrangement of thick-walled peridial hyphae and appendages of the reticuloperidium. X200.

**b** Smooth-walled oblate ascospores, narrowed at the margin. X6755.

a



b

Plate 5.1.

a *Gymnascella (?)candidus* (TRTC Sydow 4031). Conglobate ascospores. X9500.

b *Diehliomyces microsporus* (PREM 33387). Smooth, globose, thin-walled ascospores with central oil droplet. X1380.

c *Gymnascella devroeyi* (RSA 1481). Oblate, smooth, thick-walled ascospores. X1300.

d *Gymnoascus intermedius* (TRTC 45468). Arrow indicates swollen element of peridial hypha. X715

e *Gymnoascus intermedius* (TRTC 45468). Extensive development of thick-walled, straight peridial hyphae. Arrows indicate location of clusters of asci. X360.

f *Gymnoascus intermedius* (TRTC 45468). Branches of peridial hyphae are at right angles. X715.

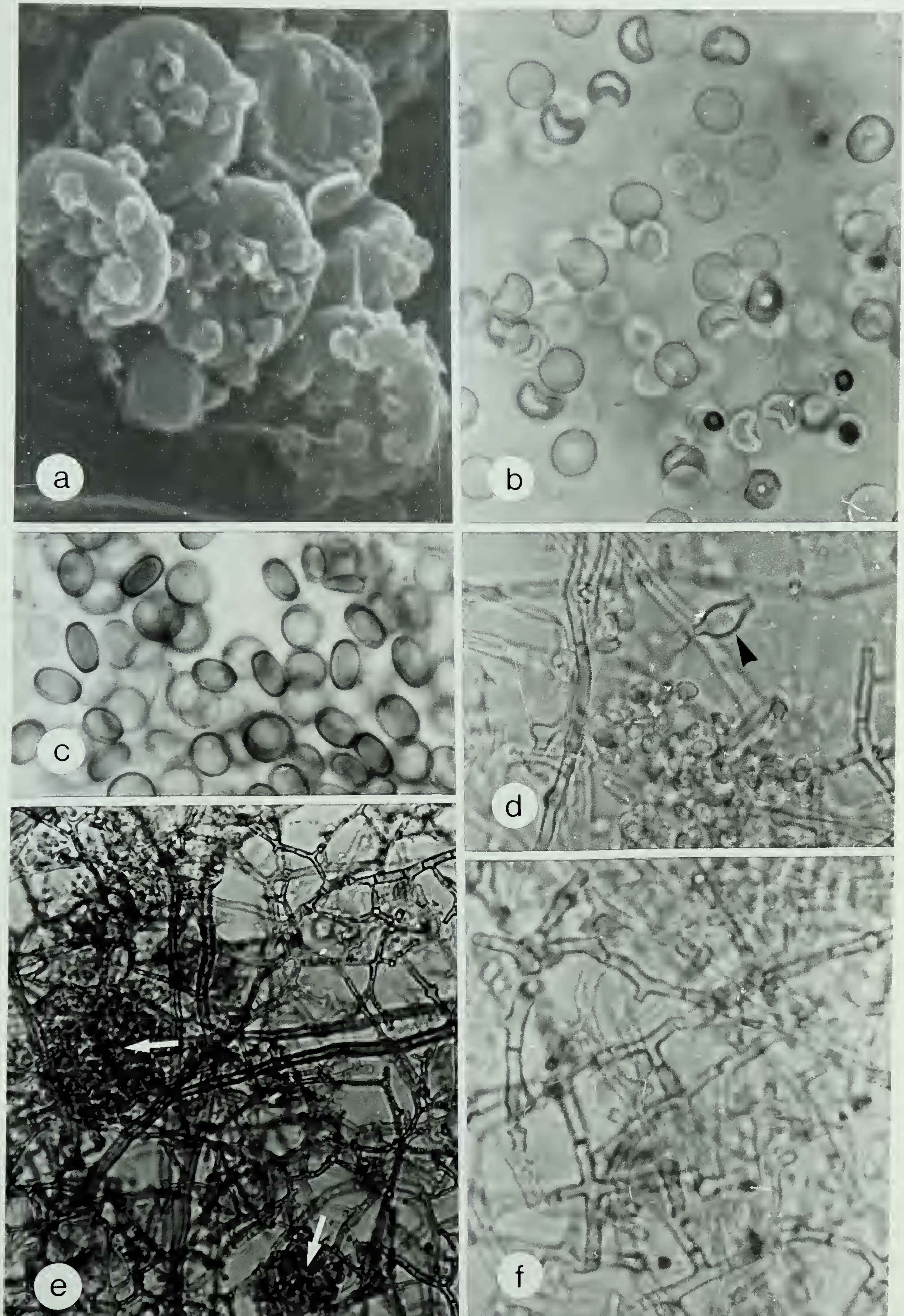

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Plate 5.2.

**a** *Gymnascella citrina* (UAMH 3545). Typical globose asci. Ascospores have polar thickenings and slightly irregular ("lumpy") surfaces. X1800.

**b** *Gymnascella littoralis* (NY O-3885). Smooth, flattened-oblate, thick-walled ascospores with equatorial band, and asci. X1355.

**c** *Gymnascella nodulosa* (RSA 1552). Smooth, thick-walled, nodulose peridial hyphae. X1445.

**d** *Gymnascella nodulosa* (RSA 1552). Thick-walled, swollen element with constriction at septum. X1445.

**e** *Arachniotus ruber* (FH "dog dung, Argentina"). "Pulley-wheel" shaped ascospores and globose asci. X1300.

**f** *Talaromyces flavus* (TRTC "date, 1958"). Thick-walled, spiny, ovoid ascospores. X1315.

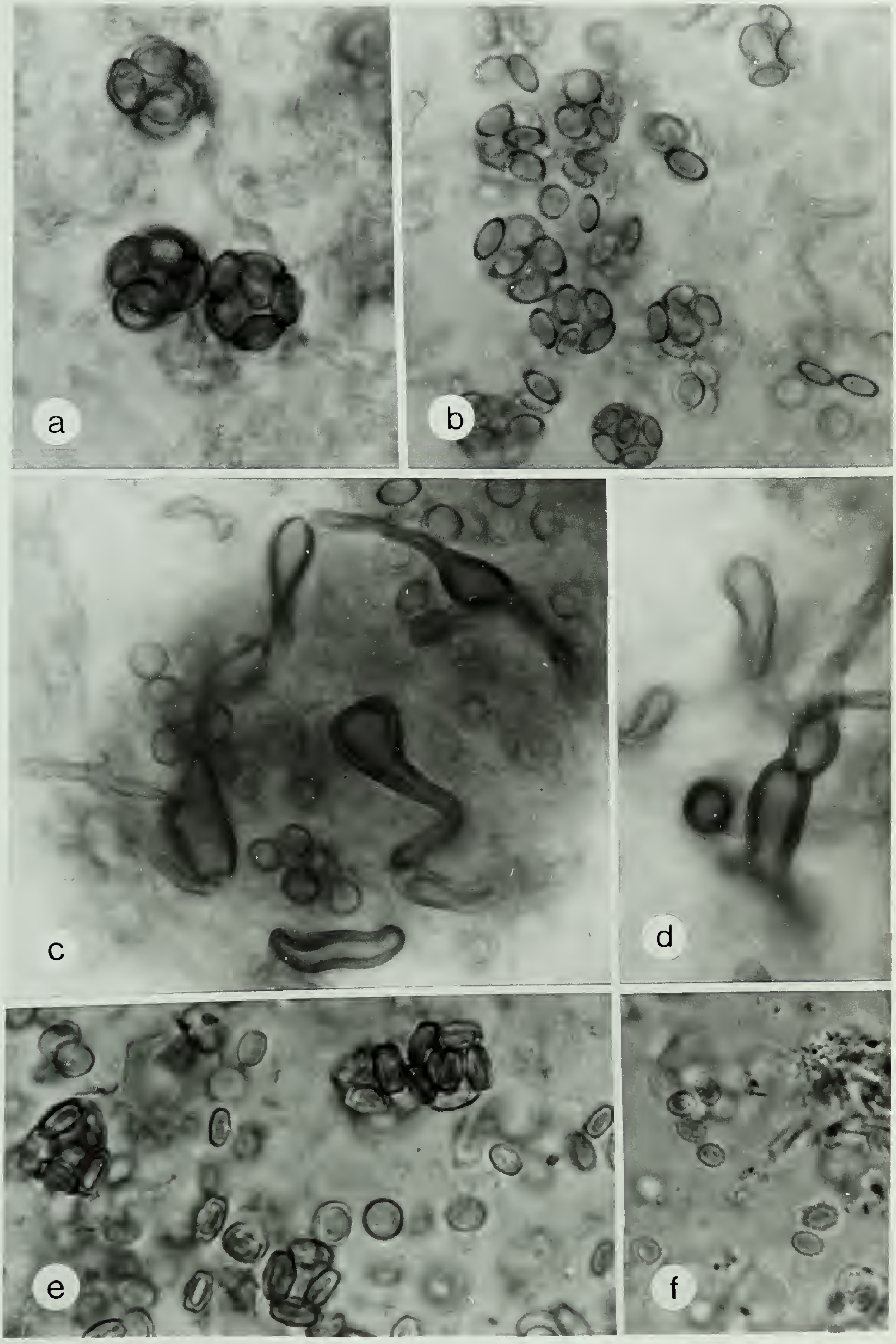
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Plate 5.3.

**a** *Gymnascella aurantiaca* (UAMH 3529). Smooth, thick-walled, oblate ascospore showing concavity with central thickening on polar face. X22500. (cf 5.3.c).

**b** *Gymnascoideus petalosporus* (UAMH 1665). Smooth, thick-walled oblate ascospore. X28000.

**c** *Gymnascella aurantiaca* (UAMH 3529). Smooth, oblate ascospore with polar concavity and some irregular polar thickening. X22500.

**d** *Gymnascella aurantiaca* (UAMH 3529). Central thickening in slight concavity in polar face. X18500.

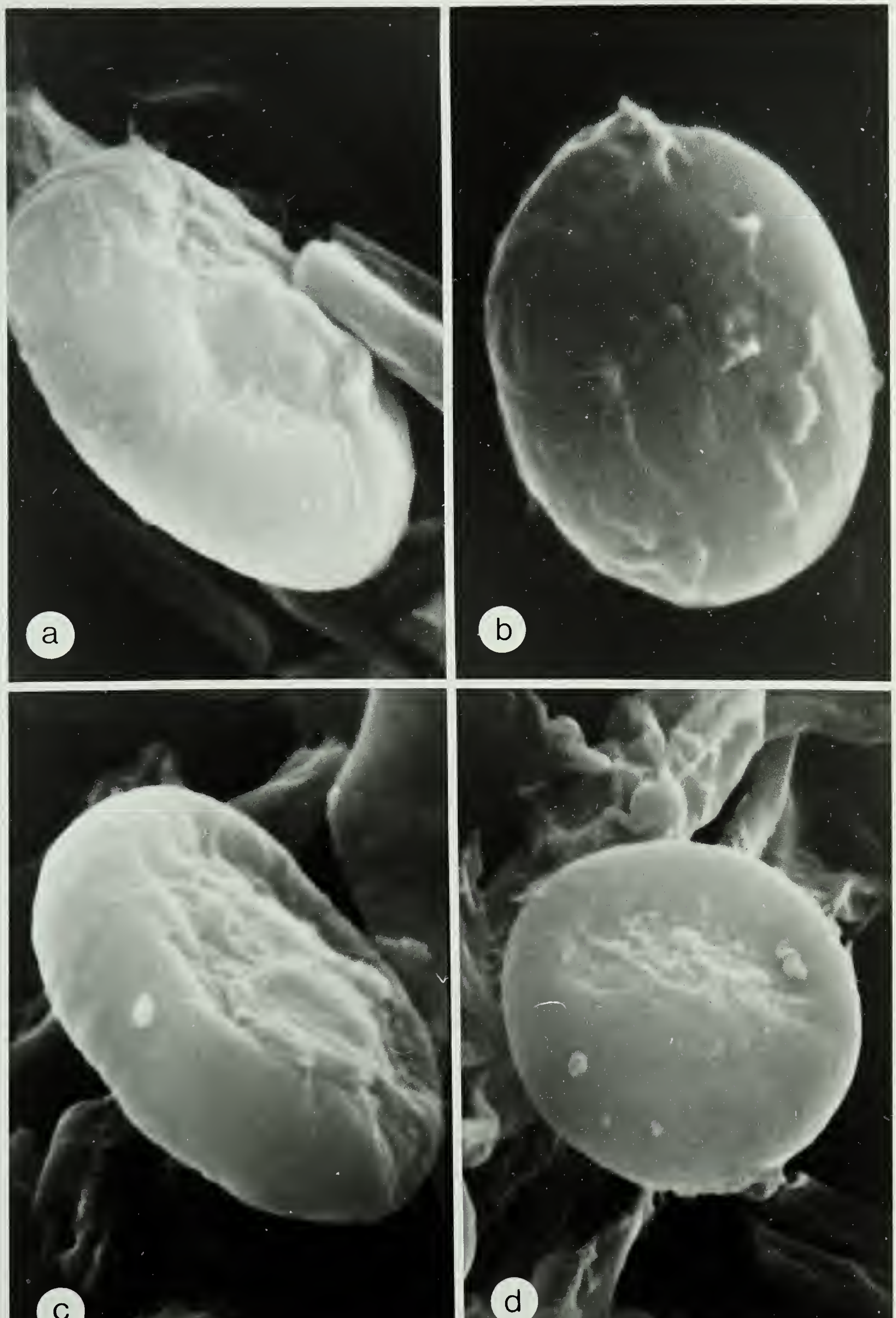
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Plate 5.4.

**a** *Gymnascella aurantiaca* (U 178821B). Ascospores in conglobate ascal clusters. X1600.

**b** *Gymnascella confluens* (RSA 1240). Individual ascospore in equatorial view showing broad marginal furrow. Conglobate ascospore cluster indicated by arrow. X1665.

**c** *Gymnascella afilamentosa* (NY O-2601). Petaloid clusters of smooth oblate ascospores. X1520.

**d** *Gymnascella confluens* (RSA 1240). Thick-walled hypha with ampulliform swelling (arrow). X1605.

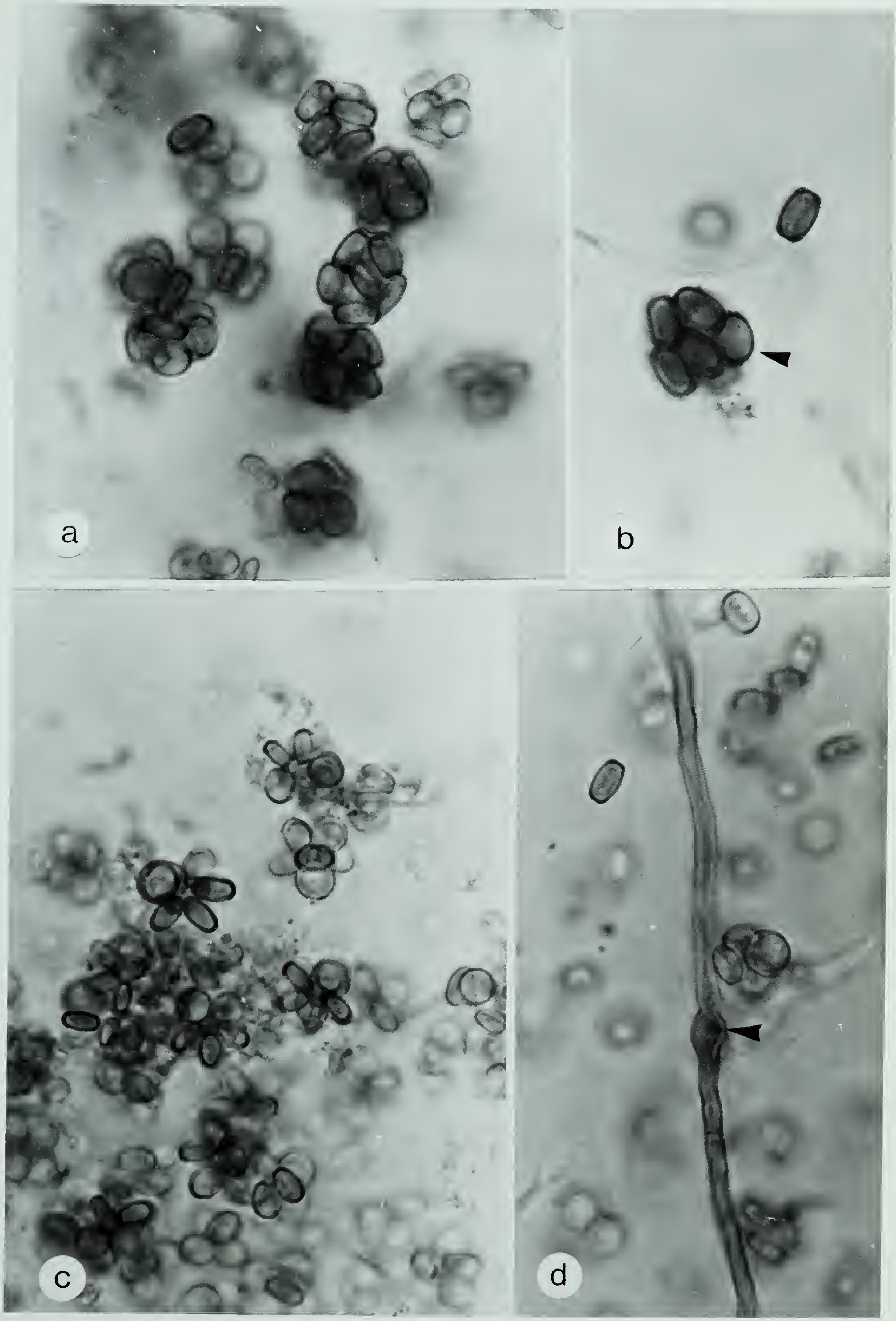
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Plate 5.5

**a** *Gymnascella afilamentosa* (UAMH 3427). Petaloid cluster of smooth-walled, oblate ascospores. X7500

**b** *Gymnascella dankaliensis* (UAMH 3531). Face view of a typical ascospore showing equatorial band and polar, boss-like thickening. X13000.

**c** *Gymnascella dankaliensis* (UAMH 3531). Oblique equatorial view of a typical ascospore showing irregular wall surface. X13000.

**d** *Gymnascella confluens* (UAMH 3565). Equatorial and polar views of typical smooth ascospores. X13000.

**e** *Gymnascella dankaliensis* (TRTC M7143). Ascospores with typical polar boss and equatorial thickening. X1170.

**f** *Gymnascella dankaliensis* (TRTC M7143). More or less globose asci and several thick-walled hyphae associated with ascospores. X1170.

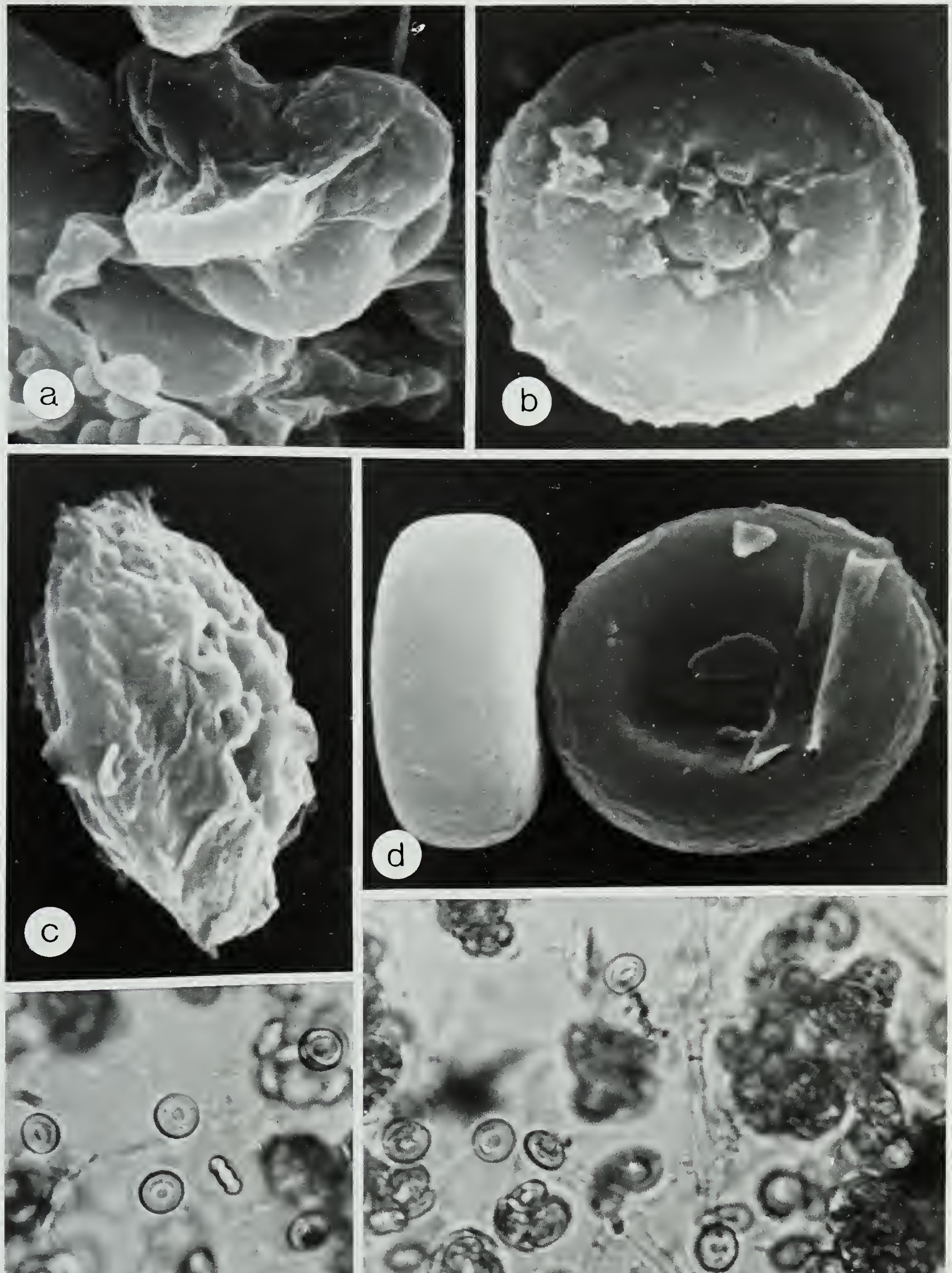
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Plate 5.6.

**a** *Gymnascella marginospora* (ANSM QM 1327). Asci and ascospores with equatorial band. X1715.

**b** *Gymnascella marginospora* (ANSM QM 1327). Smooth, thick-walled hyphae associated with ascospores. X940.

**c** *Gymnascella marginospora* (ATCC "buzzards stomach, C. L. Shear"). Thick-walled hyphae associated with ascospores. Arrows indicate ampulliform swellings. X1145.

**d** *Gymnascella punctata* (RSA 1544). Ascospores and asci. X1500.

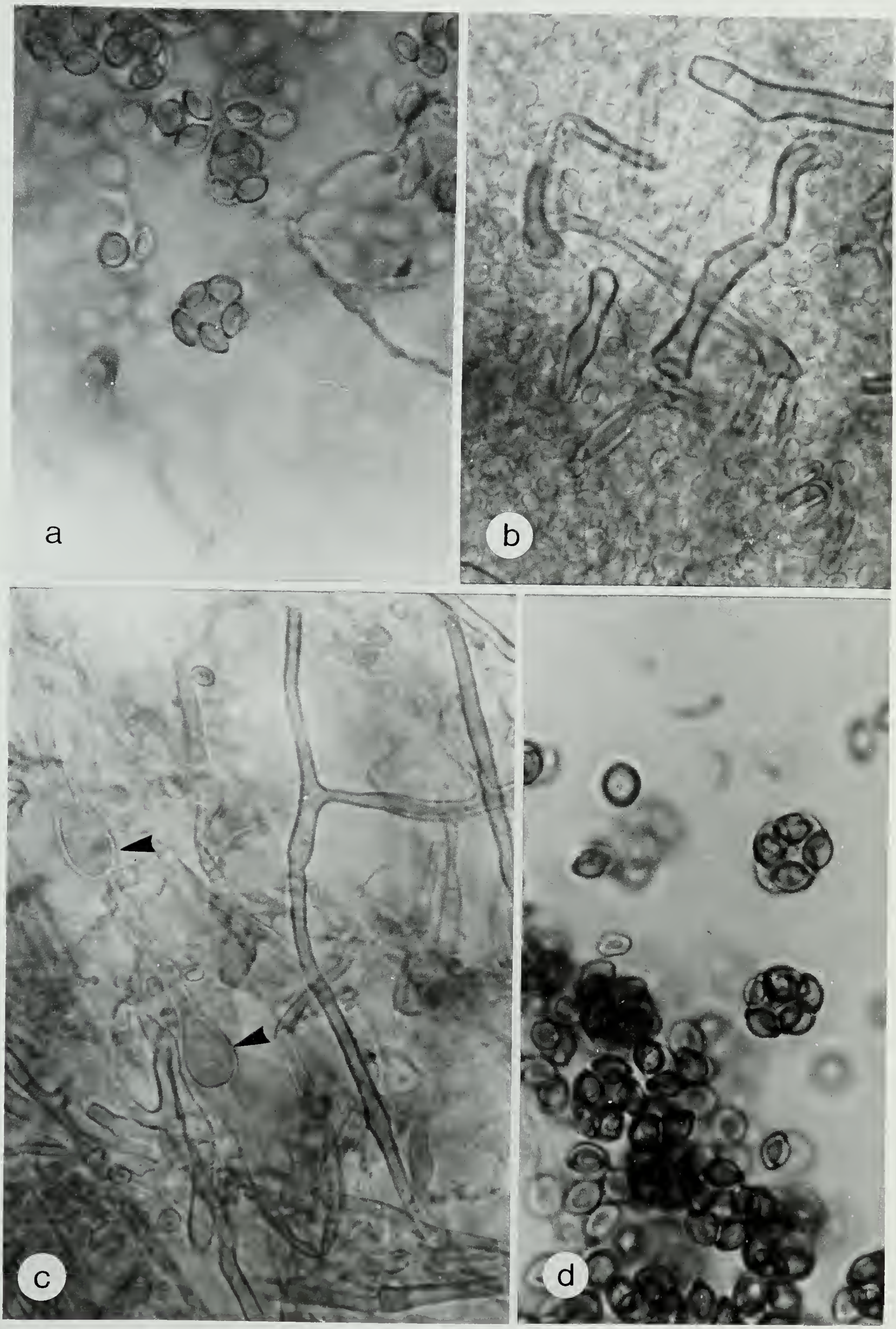
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Plate 5.7.

**a** *Gymnascella marginospora* (UAMH 3164). Thick-walled ascospores with irregular or lumpy surface. Equatorial band indicated by arrow. X13000.

**b** *Gymnascella punctata* (UAMH 3530). Thick-walled, ±oblate ascospores with broad equatorial rims. X14000.

**c** *Gymnascella dankaliensis* (UAMH 3531). Oblique polar view of ascospore. X13000.

**d** *Gymnascella hyalinospora* (UAMH 3155). Conglobate, oblate ascospores with irregular walls. X12500.

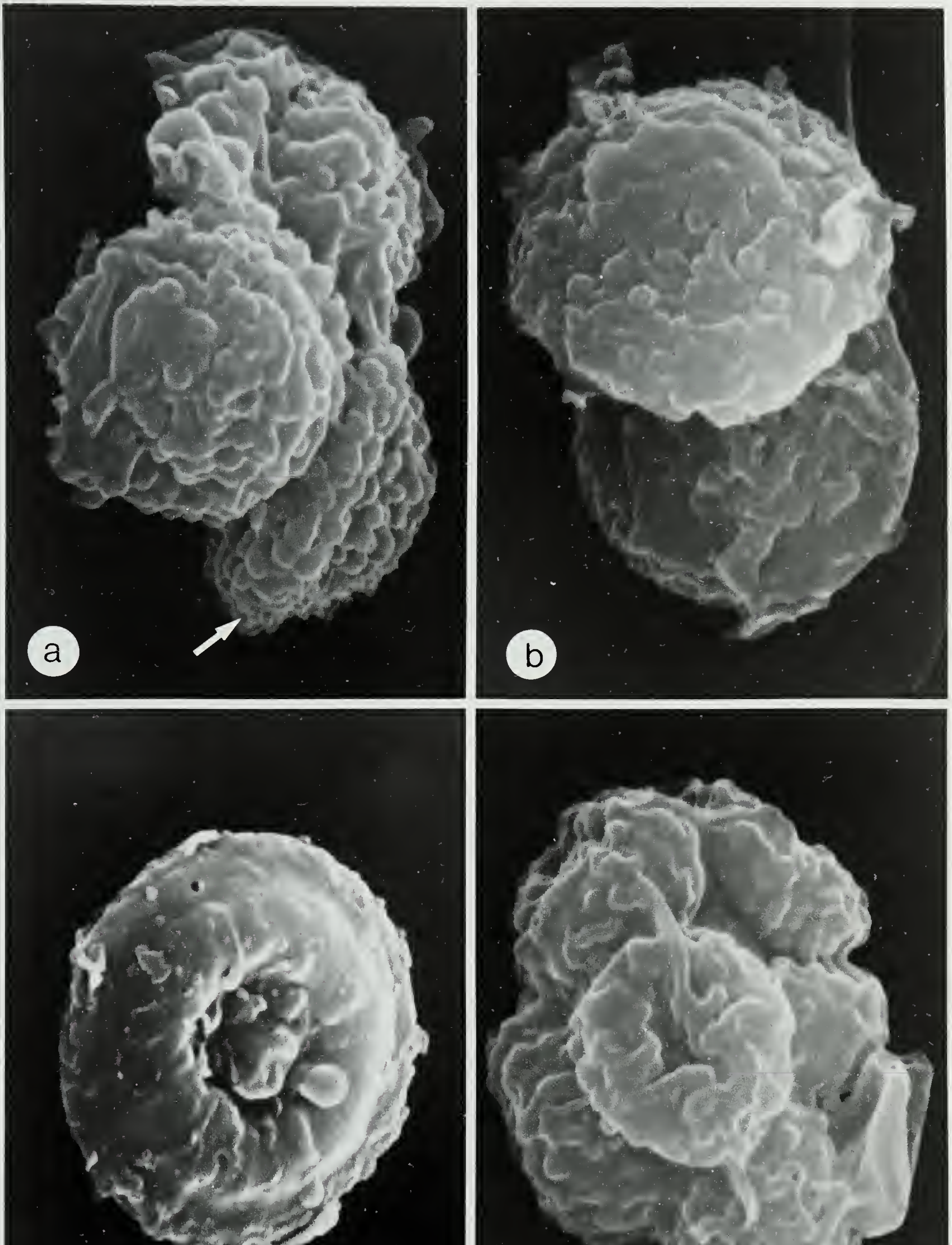
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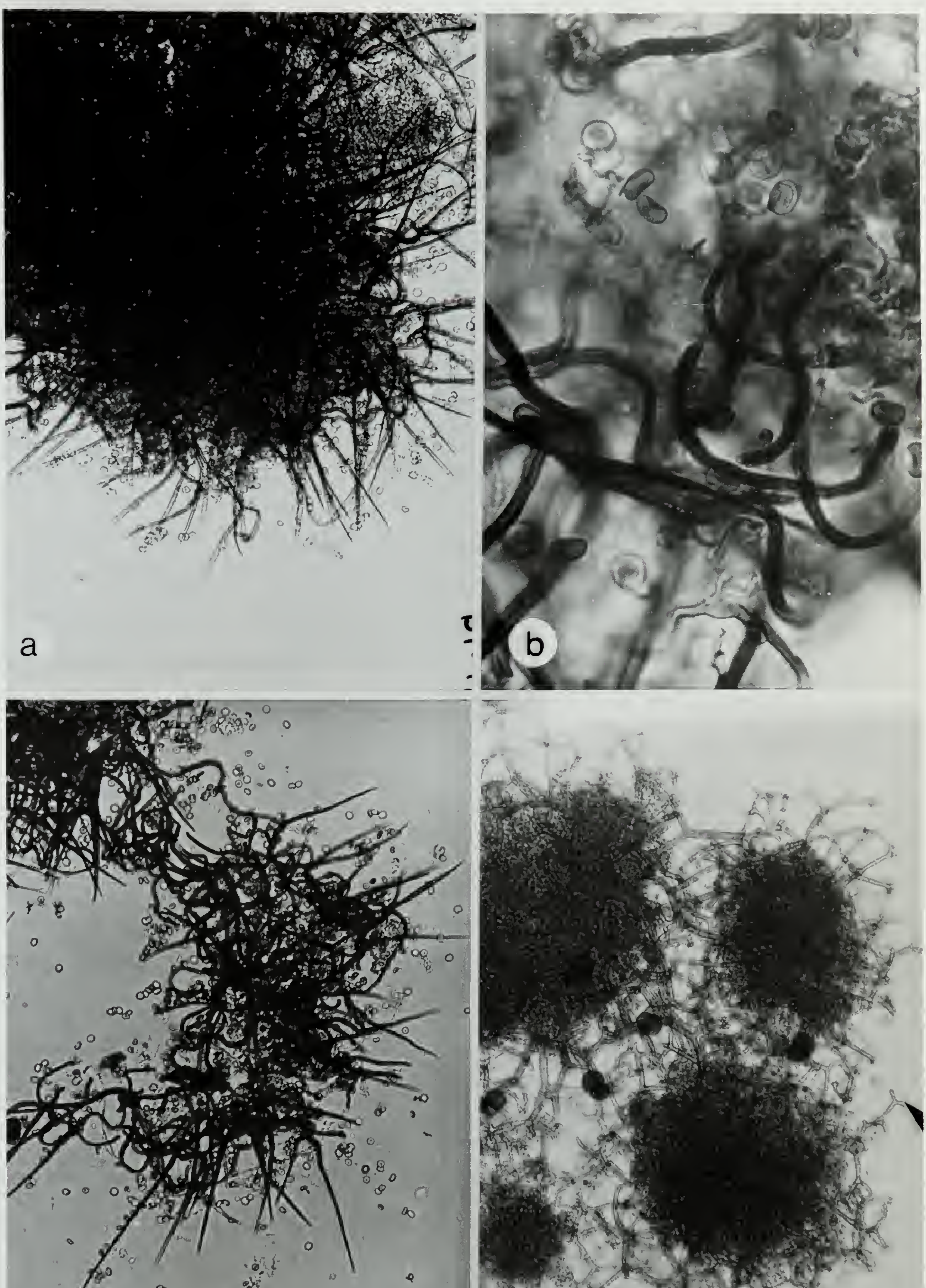
Plate 5.8.

a *Acitheca purpurea* (FH Holotype). Ascoma from type specimen with needle-like appendages. X220.

b *Acitheca purpurea* (FH Holotype). Smooth oblate ascospores and curved proximal portions of needle-like appendages. X1042

c *Acitheca purpurea* (FH Holotype). Organization of peridial hyphae and appendages. X315.

d *Gymnoascus reessii* (from coyote dung coll. UADBG, 1980). Four individual ascomata with "boat-hook" appendages indicated by arrows. X250.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# CHAPTER 6

## MYXOTRICHACEAE

Myxotrichaceae Locquin ex Currah

*Typus: Myxotrichum* Kunze.

*Ascocarpi ruber, aut rosei, aut virelli-brunnei (plerumque apparenter anthracini); ±globosi. Ascosporae hyalinae ad gilvae aut roseae, late ellipticae aut fusiformae, levae aut cum striis. Asci globosi aut subglobosi. Hyphae peridii lutea, rosea aut roseobrunnea, crasso-parietales, levae aut asperulatae, septatae ramosae. Appendicula destitutae, aut brevae aut elongatae; lutea, rosea aut roseobrunnea, crasso-parietales, levae aut asperulatae, septatae ramosae; acutae aut obtusae, rectae aut unciformae. Homothallicus. Stat. conid: Geomyces, Oidiodendron et conidia alternatae sine nomine.*

**Ascomata:** rose or deep reddish or greenish brown (often appearing black), ±globose reticuloperidium (absent in one genus) of asperulate, septate hyphae. **Ascospores:** hyaline to pale yellow or rose, ellipsoid or fusoid, smooth or long-striate, rather thin-walled, <6.0$um$ long, (one species with ascospores as long as 14$um$). **Asci:** hyaline, globose or subglobose, diam. rarely greater than 12$um$ (one species to 20$um$). **Peridial hyphae:** yellow, rose or reddish brown, thick-walled, smooth or asperulate, septate, branched, often terminating in "witches' brooms" of short acutely pointed branches. Peridium absent in one genus. **Appendages:** present or lacking, pigmented, forming long croziers or hooks, or consisting of long or short, ±straight, pointed or blunt ends of peridial hyphae. **Thallism:** homothallic. **Anamorphs:** *Geomyces, Oidiodendron* and unnamed arthroconidial anamorphs.

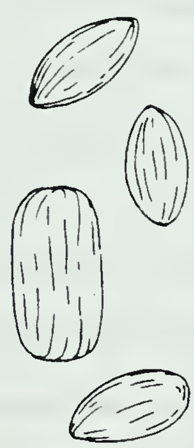
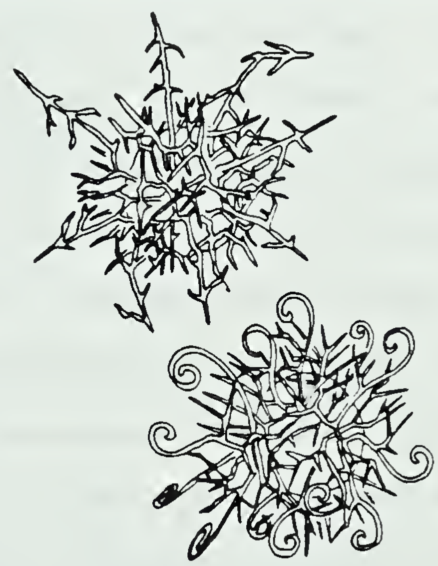
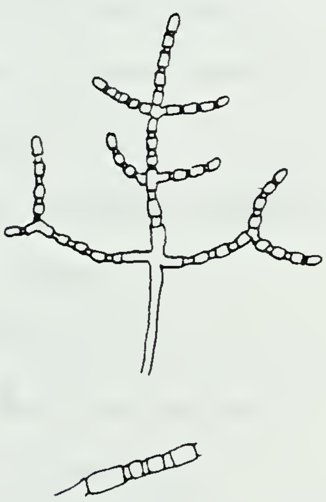
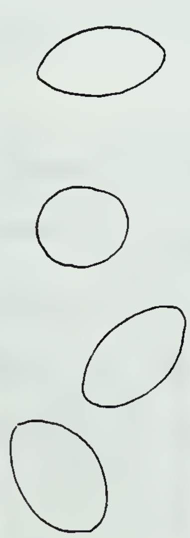
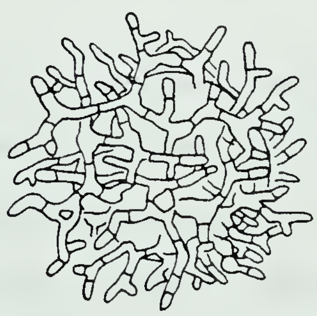
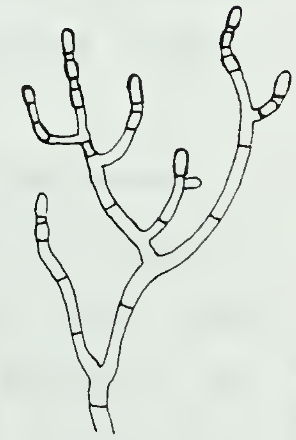
**Notes:** Locquin (1974) proposed the family Myxotrichaceae but did not validly publish the name (Eriksson, 1982). Von Arx (1981b) suggested that a new family might be appropriate for *Myxotrichum* and its allies. The Myxotrichaceae here includes the cellulolytic Onygenales. These species are distributed among three genera: *Byssoascus, Myxotrichum*, and *Pseudogymnoascus* (Table 6.1). They form what appears to be a homogeneous group based on their cellulolytic capacities, ascospore morphology and anamorph characteristics. Peridial morphology varies from telathecia in *Byssoascus* to elaborate and appendaged

reticulothecia in *Myxotrichum*. No membranous forms are known although a collection at DAOM (176970a, coll. George White, rotting conifer log, Waterton National Park) appears to represent a new genus of the Myxotrichaceae with a membranous peridium. Ascospores are characteristic of the family (fusoid, striate, yellow, 1.6-2.1 x 3.9-4.5$\mu$m). These are borne in an easily-ruptured, membranous cleistoperidium. An *Oidiodendron* state was cultured from the substrate but its relationship to the ascospores has so far not been determined. A detailed report must await further study of the material.

Although *Pseudogymnoascus* is frequently found during studies of the flora of higher plant rhizospheres, most species in the family are rarely encountered. Habitat and cultural evidence suggests that the Myxotrichaceae may be a psychrophilic group (optimum temperature <18°C). Although one or two isolations have been obtained from animal sources (fingernail, dog lesion), there is no evidence that any of these taxa are pathogenic.

TABLE 6.1

GENERA OF MYXOTRICHACEAE

| Genus | Ascospores | Peridia and Appendages | Anamorphs |
| --- | --- | --- | --- |
| Byssoascus |  |  |  |
| Myxotrichum |  |  |  |
| Pseudogymnoascus |  |  |  |

## BYSSOASCUS Von Arx, 1977

Persoonia **6**:377.

**Type species:** *Byssoascus striatosporus* (Barron and Booth) Von Arx *op. cit.*

**Ascomata**: white, globose. **Ascospores**: hyaline to pale yellow, fusiform, striate. **Asci**: ovoid. **Peridial hyphae**: hyaline, thin-walled, apparently undifferentiated. **Appendages**: lacking. **Anamorph**: alternate arthroconidia.

*Byssoascus striatosporus* (Barron and Booth) von Arx, 1971 Persoonia **6**:377.

**Type material**: HOLOTYPE (*cultura desiccata*) **CMI** 115998 (soil, Ontario).

≡*Arachniotus striatosporus* Barron and Booth, Can. J. Bot. **44**:1060, 1966 (Basionym).

≡*Myxotrichum striatosporum* (Barron and Booth) Sigler, Mycotaxon **4**:385, 1976.

**Anamorph name**: *Oidiodendron, fide* Sigler and Carmichael, 1976.

**Ascomata**: white, cottony telaperidium, often confluent, 100-200$um$ diam (*fide* Barron, *op. cit.*); ±fascicular bundles of thick-walled, dark hyphae form in culture *fide* Sigler and Carmichael (1976). **Ascospores**: greenish yellow, fusiform, striate, 1.5-3.0 x 4.5-6.5$um$. **Asci**: ovoid to clavate. **Peridial hyphae**: hyaline, mostly undifferentiated from vegetative hyphae. Some brown, thick-walled, smooth, branched hyphae present. **Anamorph**: arthroconidia olive-green, slightly asperulate, barrel-shaped, 1.5-2.5 x 1.5-3.5$um$, borne on narrow, hyaline conidiophores or on apparently undifferentiated hyphae. **In culture**: [UAMH 3572]. CER 42/25°C olive-green, slightly zonate, margin yellow; reverse light brown. DSA 42/25°C pale cream-colored, scant. PYE 35/25°C abundant green-gray growth, mat puckered and heaped; reverse dark reddish brown.

**Notes**: Barron and Booth (1966) do not mention the dark, thick-walled peridial elements (observed by Sigler and Carmichael (1976), in their original description of this species. The *Oidiodendron* anamorph, yellow, striate, fusoid ascospores and the ability to break down cellulose, place this species in the Myxotrichaceae. The peridium is the distinction at the genus level. Known only from the type.

**Material examined:** UAMH 3572 (type strain as cited, obtained from CBS).

**MYXOTRICHUM** Kunze, 1823

Mykol. Hefte **2**:109.

**Type species:** *Myxotrichum chartarum* (Nees) Kunze.

=*Campsotrichum* Ehrenberg, 1819. (non Necker, 1770 and *nomen invalidum fide* Hughes, 1968).

≡*Actinospira* Corda, 1854.

=*Eidamella* Matruchot and Dassonville, 1901.

?=*Tripedotrichum* Orr and Kuehn, 1964a.

=*Toxotrichum* Orr and Kuehn, 1964b.

**Ascomata:** dark reddish or greenish brown to almost black, ±globose, often confluent, especially on natural substrata. **Ascospores:** hyaline to pale yellow, ellipsoid or fusoid, often with one end broader than the other, thin-walled, longitudinally striate. Striae few to numerous, pronounced or barely discernible. **Asci:** hyaline, ±globose. **Peridial hyphae:** reddish brown, thick-walled, cuticularized, (shiny), usually richly branched and sometimes anastomosed, always forming a reticuloperidium. **Appendages:** septate, elongate, straight or curved, simple or branched, tips straight, bent, curved or uncinate, ±branchlets. **Anamorph:** aleurioconidia and arthroconidia; some assignable to *Malbranchea* and *Oidiodendron*.

**Notes:** Nees (1823) first described *M. chartarum* in a new genus which he called *Oncidium*, a name which was already occupied in the Orchidaceae. Kunze (1823) renamed the genus *Myxotrichum* and it then became a repository for everything from a variety of dematiaceous hyphomycetes to reticulothecial ascomycetes with hooked appendages (Schroeter, 1893). Kuehn (1956) and Orr, Kuehn and Plunkett (1963c) give comprehensive historical accounts of the genus. The genus is still poorly understood, due in part to the paucity of isolations available. Orr, Kuehn and Plunkett *op. cit.* monographed the genus and Orr and Kuehn (1964 a,b) later described the apparently related genera, *Toxotrichum* and *Tripedotrichum*. *Tripedotrichum* was described as a *Myxotrichum*-like genus with brown, oblate ascospores. I have examined the type material and I suspect that

Orr and Kuehn mistook the dematiaceous conidia of a hyphomycete (possibly *Stephanosporium cereale*) for ascospores. Further comments on this name should await the availability of cultures of the fungus producing the interesting tripod-shaped appendages (setae?). Von Arx felt this taxon represented a *Gymnoascus* species since the "appendages" were similar to *Gymnoascus uncinatus* and to *Uncinocarpus reesii*. *Toxotrichum* was erected for *Myxotrichum cancellatum*, since unlike other *Myxotrichum* species, peridial hyphae were roughened and lacked free apices. There is no need to keep this species in a separate genus. The nature of the reticuloperidium and the color and morphology of the ascospores place it well within the concept of the genus *Myxotrichum*.

Apinis (1964), arranged the species of *Myxotrichum* among four subgenera: *Eidamella Myxotrichum*, *Pseudomyxotrichum*, and *Tripedotrichum* to recognize variation in appendages.

Some dematiaceous hyphomycetes bear setae which are strikingly similar to elements of *Myxotrichum* reticulothecia (e.g. *Gyrothrix podosperma* see PL 6.1f).

*Myxotrichum aeruginosum* Montagne, 1836 Ann. Sci. Nat. Bot. II 6:30.

PL 6.2f

**Type material:** HOLOTYPE (natural material). K "ex Montagne" (cardboard, France).

**Ascomata:** dark brown to black, spherical, 170-350µm diam., excl. appendages. **Ascospores:** pale yellow with a faint greenish cast, smooth, ovoid, ellipsoid to fusoid 1.6-3.0 x 3.0-5.5µm. **Asci:** hyaline, subglobose to ellipsoid, 8.0-10µm. **Peridial hyphae:** dark brown to almost black, branched, thick-walled, ending in a few elongate appendages; numerous, short, awl-shaped spines, 30-65µm with branches at 60° angles at base of appendages. **Appendages:** dark brown, fading and tapering toward apex, up to 7-8-septate, straight, bent, apically uncinate (but not enlarged), 70-250µm in length, 3.8µm wide at base. **Anamorph:** some arthroconidia recorded. **In culture:** [no cultures].

**Notes:** *Myxotrichum aeruginosum* and *Myxotrichum ochraceum* have been

frequently confused. An historical account of the problems in distinguishing between these two species is provided by Orr, Kuehn and Plunkett (1963c). Unfortunately, they also confused the species by calling Roumeguere 7366 "*Myxotrichum ochraceum*" when it is actually a fine example of *M. aeruginosum*. The two species are also confused with *Myxotrichum stipitatum* which in turn is close to *Myxotrichum setosum*. An adequate treatment of the taxonomy of these species must await further isolations, since *M. aeruginosum* is known only from dried material.

**Material examined:** as *Myxotrichum aeruginosum*: **BR** ?/burlap sacking?/?; **DAOM** 50964 (ex Uppsala)/rotten cloth/Sweden?; 49096/sacking/Strasbourg?.

*Myxotrichum berkeleyi* Apinis, 1964 Mycol. Pap. **96**:17-19, FIG 2a-d.

**Type material:** HOLOTYPE (*cultura desiccata*) **CMI** 57211 (pine deck planking, Britain).

**Ascomata:** brown to black, single, clustered, 150-300um excl. appendages. **Ascospores:** pale yellow (hyaline), smooth or finely striate, 1.5-2.5 x 3.2-4.5um. **Asci:** subglobose to ovoid, 6.9um diam., 8-spored. **Peridial hyphae:** brown, septate, smooth, branched, loosely interwoven. **Appendages:** brown, ±striate, 2-6um wide and 200-450um in length, basal branches deflexed. **Anamorph:** aleurioconidia present in type strain (UAMH 1658). **In culture:** [UAMH 1658]. CER 38/25°C white to gray, felty; reverse yellow-orange. DSA 54/25°C ring of orange-brown mycelium surrounded by cloudy growth. PYE 28/25°C fuzzy, felt-like, yellowish orange to gray, slightly granular; reverse orange brown.

**Notes:** The type strain has failed to fruit at UAMH and the above description is largely taken from the original.

**Material examined: UAMH** 1658 from Orr as O-2513 (1963). (O-2513 also applied by Orr to a collection of *Pseudogymnoascus roseus*.

*Myxotrichum bicolor* (Ehrenberg) Fries, 1832 Systema Mycologicum **3**:351.

PL 6.1b, 6.2d

**Type material:** HOLOTYPE (natural material) **L** ex Herb. Persoon (*Usnea plicata*, Germany).

=*Campsotrichum bicolor* Ehrenberg, Hor. Phys. Ber. 32, 1820 and Link's Jahrb. Gewachsk. II 1:32, 1819. (Basionym).

=*Myxotrichum poluninii* Apinis, Mycol. Pap. **96**:26, 1964.

**Ascomata:** dark grayish brown to black, gregarious to confluent, on lichen thalli, individual ascospore clusters 50-800*um* diam. **Ascospores:** hyaline to yellow-brown, ellipsoidal, ends broad or flattened, 3.0-6.0 x 8.0-14*um*. **Asci:** irregular to mostly obovoid, 10-14 x 14-19*um*. **Peridial hyphae:** (No distinction can be made between peridial hyphae and appendages). Peridial hyphae and appendages brown, smooth, branched, septate, 1.5-5.5*um* diam., proximal portion with delicate witches' brooms; distal portion becoming greater in diam., septate or aseptate, with curved to uncinate lateral branches. **Anamorph:** unknown. **In culture:** no known cultures.

**Material examined: DAOM** 49089/lichen/?; 50164, 50173 ex Persoon/Leiden?; **LE** ex Herb; Chamisso/lichen/?; as *Gymnoascus* sp.: N26/511/lichen/USSR.

**Notes:** Apinis (1964) described *Myxotrichum poluninii* based on material on a collection of *Cetraria* from Akpatok Island, Canada. Hughes' (1968) study of the type provides a good summary of the nomenclature of the species and gives photos of the holotype. This taxon is listed by Vouaux (1914) and Keissler (1930) as a *Myxotrichum* on lichens. Apparently a lichenicolous member of the Myxotrichaceae, and probably represents a new genus, due to its habitat and large blunt-ended ascospores.

*Myxotrichum cancellatum* Phillips, 1884 Grevillea 13:51-52.

PL 6.1c

**Type material:** HOLOTYPE (natural material) K Herb. William Phillips (stem of *Bartsia odonites*, Britain).

=*Myxotrichum spinosum* Massee and Salmon, Ann. Bot. **16**:64, 1902.

=*Toxotrichum cancellatum* (Phillips) Orr and Kuehn, Mycologia **63**:191-203, 1964b.

**Ascomata:** brown, globose, 100-350*um* diam. **Ascospores:** hyaline, ellipsoidal, smooth, 1.0-2.0 x 3.0-4.0*um*. **Asci:** globose to subglobose, 4.0-6.0 x

5.0-7.0*um*. **Peridial hyphae:** dark brown, minutely asperulate, 2.5-5.5*um* diam. **Appendages:** dark brown, radiating spines, to 350*um* long, smooth, 3.0-5.0*um* at base, 1-2 septate, tapering toward apex. arising from arched asperulate hyphae of the peridium. **Anamorph:** arthroconidia olive brown, smooth, 2.0-2.5 x 2.5-3.5*um*. **In culture:** [UAMH 1996]. CER 14/25°C dark, grayish brown, felty; reverse with pale rose hue. DSA 42/25°C dark, grayish or olive-colored with darker perimeter, halo of white (gray speckled mycelium). PYE 28/25°C grayish charcoal; reverse brownish red.

**Notes:** Udagawa (1963) studied this species in culture and noted gametangial morphology. Orr and Kuehn (1964b) based their genus *Toxotrichum* on this species. They considered the straight appendages, and lack of free apices on the peridial hyphae, distinctive characters at the genus level.

**Material examined: RSA** 1248 (=UAMH, 1911) blueberry pastry/New Jersey; **NY** O-1963, K-1965, K-1983/blueberrry pastry/New Jersey; as *Eidamella spinosa*: **TRTC** Date 1957/?/?; as *Gymnoascus* sp.: **TRTC** 39451/rodent dung/Alberta; as *Myxotrichum spinosum*: **OSC** 7282/hog dung/Massachusetts.

*Myxotrichum chartarum* (Nees) Kunze, 1823 Mykol. Hefte **2:**110.

PL 6.1a, 6.2c,e

**Type material:** NEOTYPE (*cultura desiccata*) **RSA** 55 (rotting board, Massachusetts). (Designated Orr *et al.* 1963c).

≡*Oncidium chartarum* Nees, Mykol. Hefte **2:**63, 1823 (Basionym).

≡*Actinospira chartarum* (Nees) Corda, Icones Fungorum **6:**7, 1854.

=?*Dematium olivaceum* Schumacher, Enum. pl. Saell **II:**445, 1803 (?*fide* Orr *et al.*, *op. cit.*, see notes below)

=*Myxotrichum carminoparum* Robak, Naturvidensk. **71:**201, 1932.

**Ascomata:** greenish-gray, brown, black, globose, 150-600*um* excluding appendages. **Ascospores:** pale yellow to orange yellow, 2.0-2.5 x 4-4.5, broadly fusoid, with prominent longitudinal striations. **Asci:** hyaline, ellipsoid, 5.0-7.0 x 6.0-8.0*um*. **Peridial hyphae:** dark brown to almost black, profusely branched (sometimes dichotomously), smooth, thick-walled, shiny, 1.7-3.3*um* thick and ending in numerous spines. **Appendages:** dark brown, shiny, rigid, elongate,

uncinate, septate, 50-180*um* long, 2.3-3.3*um* diam. at base, enlarging to 4.5-6.4*um* diam. at apex. Apices subacute or rounded. **Anamorph:** aleurioconidia and arthroconidia, solitary or in chains, 1.3-3.3 x 3.2-8.0*um*. **In culture:** [UAMH 1598]. CER 28/25°C felty, tan yellow, rippled, convoluted, restricted growth; reverse purplish yellow. DSA 28/25°C yellowish, felty with peppering of black ascomata; reverse yellowish orange. PYE 28/25°C convoluted, wrinkled, reddish brown with white overgrowth; some black tinged heaped areas; reverse yellow.

**Notes:** Hughes (1968) presents an interesting discussion of some *Myxotrichum* synonyms listed by Fries. He does not discuss the synonyms in Orr *et al.* Regarding *Dematium olivaceum*, Orr's group does not mention why it is a synonym, or if the type had been examined. From Schumacher's description, *D. olivaceum* could be a dematiaceous hyphomycete. Further comment on this name must await an examination of the type material.

*Myxotrichum chartarum* produces a beautiful ascoma with striking uncinate appendages. It would be of interest to know the range of variability of these appendages and of the species in general. Orr *et al.* observed that the uncinate appendages were flattened at the distal end causing them to appear wider. *M. chartarum* is a slow-growing species intolerant of high temperatures. This species grows well (but slowly) at temperatues as low as 5-7°C, and produces a diffusible red-brown pigment on some media. Robak (1932) described *Myxotrichum carminoparum* (Robak, Naturvidensk. **71**:201, 1932 FIG 1-3) as a species smaller than *M. chartarum* and differing in producing a red pigment on artificial media. His collection also had circinate appendages but these lacked the characteristic swellings in the apical region such as are found in *Myxotrichum chartarum*. In all other respects the isolate was identical to the type of *Myxotrichum*. The type strain of *M. carminoparum* (from wood pulp, Norway) has not fruited in UAMH. However, I do not feel the reported differences merit its retention as a separate species. Orr reports that this species does not grow at 37°C but will grow at +7 or -2 °C. A somewhat intermediate form was reported by Udagawa (1963). His collection resembled *Myxotrichum carminoparum* in its small size of the ascomata but because it had "inflated circinate" appendages, he placed it in *Myxotrichum chartarum*.

**Material examined: AMD** 179/paper/Dresdae with *M; deflexum*; **AMD, FH, G** George Winter, Fungi Europaei 1169/moist paper/Lipsiae?; **ANSM, G, HBG, MICH, NY** P;L; Ricker, Fungi Columbiani 1360/damp paper/Maine; **BR** Bommer and Rousseau/old newspaper/France?; Bommer and Rousseau/paper/France?; Magnagutim/music paper/France; Mme Rousseau/paper culture/France; Mme Rousseau/fiber culture/France; **BR, DBN, G, HBG, LE, TRTC** Zahlbruckner, Flora Austro-Hungarica 3180/paper/Austria; **BR, G** 179/paper/location undetermined (with *Myxotrichum deflexum*); **BR, G, LE, NY** Vindobonensi 2526/paper/Czechoslovakia; **BR, LE** Desmazieres/paper/France; **BR, LE, PAV** Rabenhorst 1169/paper/Lipsiae; **DAOM** 136693/rabbit dung/Ontario; 136710/rabbit dung/Ontario; 40998a/rotten paper/Czechoslovakia?; 49095 ex herb Inst. bot Strasbourg on sac-like material; 50966 ex Uppsala/cloth/Sweden?; **DBN** 207/grass/Ireland (King's Cliffe); **E** Saccardo 207/paper/straw/England; ?/cardboard/New York; Flora Exsiccata/paper/Austro-Hungarica; CMI 89072a&b/cardboard/England; **FH(P)** 431/S4793/leaves and fruit of *Carex* sp. sp;/location undetermined; **G** "vieux papier humide"/paper/France; Delessert 760/paper/France; Herb; Barbey Boisier?/paper/Leipzig; 106/paper/France; **HBG** ex Herb; Eichelbaum/paper/Germanywith dematiaceous conidial fungi; ex Herb. Richter/paper/Germany; **HBG, LE** Rabenhorst 1169/paper/Germany; **HBG, MICH, PAV, NY, TRTC** Cavara, Fungi Longobardiae 47/paper/Ticinensis; **HBG, NY, PAV** Saccardo 276/rotten paper/Italy; **LE** TIPO Auerswald/paper/Germany; **NY** ex Herb. George Massee/grouse dung/Balmoral Forest; Desmaziere 760/wet paper/France; **NY, RSA** 55/rotten board/GermanyNeotype; **PAV** Herb. Ticinensis 415/paper/Italy; 106/paper/France; **RSA** 1191/cardboard/England; **TRTC** Paris 1134/rabbit dung/France?; **UAMH** 1997/soil/Japan; **UAMH, NY** 1598 (=CMI 89072a)/cardboard/England; **UPS** E; Fries/rotten cloth/France; **WIS** Ricker 534/paper/Maine; (as *Gymnoascus chartarum*): **FH, TRTC** Thaxter 5347/tarred paper/Maine; as *Gymnoascus* sp.: **O** ?/paper/Norway?.

*Myxotrichum deflexum* Berkeley, 1838 Ann. Nat. Hist. **1**:260.

FIG 6.1, PL 6.1e

**Type material:** NEOTYPE (*cultura desiccata*). **NY** 0-249 (soil, California). (Designated Orr *et al.*, 1963c).

=*Eidamella deflexa* (Berkeley) Benjamin, Aliso 3:313, 1956.

=*Eidamella spinosa* Matruchot and Dassonville, Bull. Soc. Mycol. Fr. **17**:123, 1901.

=*Eidamella papyricola* Saccas, Bull. Soc. Mycol. Fr. **66**:121, 1950.

**Ascomata:** dark brown to almost black, globose, 200-450um diam. excl. appendages. **Ascospores:** hyaline to pale yellow, ovoid, long-striate, 2.4-2.9 x 3.6-5.5um. **Asci:** hyaline, obovoid to slightly clavate, 4.2-8.8 x 8.8-12.6um. **Peridial hyphae:** dark brown, septate, branched, thick-walled, smooth, 2.6-5.8um diam. **Appendages:** dark brown, monopodially branched, up to 200um long, lateral branches sinuate, apices rounded, ±deflexed, to 60um long; apices hyaline, 3.4-8.8um at base. **Anamorph:** alternate arthroconidia infrequent. **In culture:** [UAMH 1651]. CER 21/25°C cream, felty, concentrically zonate; reverse yellow to ochre. DSA 28/25°C deep rose red, with clusters of black ascomata; reverse rose pink to hyaline at margin. PYE 21/25°C yellow, rugose wrinkled, felty, growth appressed; reverse deep rose. (Produces large amounts of diffusible red pigment).

**Material examined: BR, G, HBG, LE, NY, PAV, PREM, RBH, TRTC, WIS** Rabenhorst Fungi Europaei 2464/paper/England; **DAOM, TRTC** 146071/air of dwelling/Ontario; **E** ?/plaster board/Scotland; **FH** Orr 1075/?/?; Orr 232/?/?; Orr 238/?/?; **NY** Massee/from type/?Drawing; Orr 245/soil/California; Orr 3137/sand/Utah; Orr 3227/sand/Utah; 78-236A/*Solidago* sp. gall/Connecticut; **NY, RSA** 57/rotting board/Massachusetts; **NY, TRTC** Roumeguere 7366/rotten straw/France (with *Myxotrichum ochraceum*; **RSA** 203/rotten rug/California; **UAMH** 1582 (=Orr 11)/soil/California; 3200 (=CMI 109888)/soil/Ontario; **UAMH, NY** 1651 (=Orr 249)/soil/California, neotype strain as cited; as *Gymnoascus setosus*: **LE** Fungi Sibirica/?/USSR; Rabenhorst 179/paper/Italy (with dematiaceous hyphomycetes); **TRTC** Thaxter 5311/feathers/Argentina; Coll. Piquet/paper/Massachusetts; 41434/cow dung/India; as *Eidamella spinosa*:

**TRTC** 31722/fingernails/Ontario.

*Myxotrichum ochraceum* Berkeley and Broome, 1875 Ann. Nat. Hist. **IV 15**:37.

PL 6.1d

**Type material**: Uncertain. Orr *et al.* (1963c) designated "Mycotheca Italica, 192" as neotype, stating Berkeley and Broome's original material was "unavailable for study." Massee and Salmon (1902) examined two specimens labelled "*Myxotrichum ochraceum*" by Berkeley and Broome. Using the original scanty description Orr *et al., op. cit.* matched a selection from Saccardo's exsiccati. Orr *et al.* did not designate which duplicate was actually the neotype. Although choosing one of the duplicates of the "Mycotheca Italica" collection would be acceptable, an exhaustive search for the original material must first take place.

=*Myxotrichum speleum* Saccardo, Michelia **2**:554, 1882 *fide* Orr *et al.*, 1963c.

≡ *Myxotrichella spelaea* (Saccardo) Saccardo, Sylloge Fungorum **10**:593, 1892. *fide* Orr *et al.*, 1963c.

**Ascomata:** dark brown, to almost black, globose, 150-500*um* diam. (excluding appendages). **Ascospores:** pale yellow, (ochre in mass) 1.6-3.0 x 3.6-5.0*um*, fusiform, faintly striate. **Asci:** hyaline, ±globose, 4.8-8.4*um* diam. **Peridial hyphae:** dark brown, thick-walled, branched, ending in short and elongated appendages. **Appendages:** dark brown, in two length classes: "short" - 90-180*um* in length, fragile with blunt or rounded apices; and "long," 200-1650*um*, 3.3-4.4*um* at base, fragile, paling in color to tip, up to 15 septate, straight, slightly bent, or curved apically, apex blunt, rounded or truncate. primarily and secondarily branched at proximal end. **Anamorph:** absent, or hyaline, terminal, pyriform aleurioconidia or intercalary cylindrical arthroconidia. On wheat germ agar RSA 1190 has bright ochraceous yellow mycelium with very black ascomata. No UAMH cultures examined.

**Material examined: BR, DBN, G, HBG, LE, NY, PREM** Rabenhorst, 1863/rotten wood/England; **BR** ?/straw/?; **HBG, NY, PAV** Saccardo Mycotheca Italica, 192/grass basket/Italy; **NY** Massee/bark/England (drawing); **RSA, UAMH**

1190 (=UAMH, 1904)/rotten cardboard/England.

*Myxotrichum setosum* (Eidam) Orr and Plunkett, 1963 Can. J. Bot. **41**: 1470-1471.

**Type material:** NEOTYPE **CMI** 471 (beehive comb, England). (Proposed).

=*Gymnoascus setosus* Eidam, Bot. Cent. **10**:107, 1882 (Basionym).

**Anamorph name:** *Oidiodendron* state of *Myxotrichum setosum, fide* Sigler and Carmichael, 1976.

**Ascomata:** dark brown to black, globose. **Ascospores:** hyaline to pale green, fusoid with one flattened pole, 3.0-4.0 x 5.0-7.5*um*. **Asci**: ovoid, subglobose, 7-8*um* max. diam. **Peridial hyphae:** brown-black, thick-walled, septate, branches numerous, terminating in acute, spine-like apices. **Appendages**: dark brown, septate, thick-walled, with 2 or 3, opposite, short, whorled, sinuous branchlets at acute angles, often with short, pointed, lateral tooth-like projections. **Anamorph:** arthroconidia olive, thick-walled, smooth, cylindrical, developing in basipetal succession, slightly rounded, persistent, often septate, connections, 1.5-2 x 3-5*um*. **In culture:** [UAMH 3835]. CER 21/25°C grayish green, thick felty, perimeter yellow; reverse yellow with pale green tinge. DSA 42/25°C khaki, dusty appearance; reverse concolorous. PYE 21/25°C grayish green, very thick, felty, concentrically folded; reverse red or yellow-brown.

**Notes:** Illustrations can be found in Massee and Salmon (1902) and in Dale (1903), and they are relatively similar. Orr *et al.* based their description on Eidam's original. Most collections under this name are either *Myxotrichum aeruginosum* or *Myxotrichum deflexum*. Orr *et al.* (1963) suggest that the autonomy of this taxon is maintained by elaborate branching of the ascoma and short branchlets arising in whorls on the main axes.

**Material examined: CMI** 471 (=UAMH 3939)/beehive comb/England; **NY** drawing by Massee; **UAMH** 3835 (=DAOM 144716)/soil/Alberta (1975).

*Myxotrichum stipitatum* (Lindfors) Orr and Kuehn, 1963 Can. J. Bot. **41**:1471-1472 FIG 17-22.

PL 6.2b, 6.3b

**Type material:** NEOTYPE (*cultura desiccata*). **RSA** 1556 (sand dunes, England)

*fide* Orr *et al., op. cit.*

=*Gymnoascus stipitatus* Lindfors, Svensk. Bot. Tidskr. **14**:270, 1920 (Basionym).

**Ascomata**: dark brown to brown-black, globose, 130-400*um* diam. excl. appendages. **Ascospores**: hyaline to pale yellow, fusiform, 1.5-3.3 x 3.3-6.6*um*. **Asci**: hyaline, stipitate, 6.4-8.8*um*, stipes 4.8-12*um* long. **Peridial hyphae**: dark brown, thick-walled, septate, to 3.5*um* diam. branching frequently at 120 ° angles. **Appendages**: brown to brown-black, rigid, septate, straight or bent, 90-215*um* long,and paling toward apex. On proximal end, lateral branches short, truncate or stubby - <20*um*, deflexed, terminating in hyaline knobs or short branchlets. Apices fragile, hyalineand acuminate. **Anamorph**: absent or hyaline terminal and intercalary aleurioconidia. **In culture**: [UAMH 3165]. CER 42/25°C luxuriant, felty, grayish black, rose tinge at periphery. reverse brown in centre, perimeter fawn. DSA 42/25°C black, granular, ascomata on rosy pink, felty area; reverse pale orange-brown at centre. PYE 42/25°C tan with some reddish tinge; reverse yellow-orange.

**Material examined**: **DAOM** 144812, 175054, 175102/soil/Alberta. **FH, NY** O-518, O-521/soil/England. **NY** B40/?/?England. Warcup/?/England. O-655, O-2054/soil/Chile. **UAMH** 1510, 3165 (=CMI 61192, =RSA 1556)/sand dunes/England (neotype strain).

## SPECIES EXCLUDED OR REFERRED TO OTHER GENERA

*Myxotrichum aurantiacum* (Peck) Saccardo, Sylloge Fungorum **4**:319, 1886 =*Gymnascella aurantiaca* (Gymnoascaceae).

*Myxotrichum brunneum* Rostrup, Bot. Tidsskr., 19:206, 1895 =*Auxarthron umbrinum* (Onygenaceae).

*Myxotrichum caesium* Fries, Systema Mycologicum **3**:348, 1832 =*Gonytrichum caesium* Nees *fide* Hughes, 1958 (hyphomycete).

*Myxotrichum conjugatum* Kuehn, Mycologia **47**:883, 1955 =*Auxarthron conjugatum* (Onygenaceae).

*Myxotrichum coprogenum* Saccardo, Michelia **2**:372, 1881 =*Gymnoascus reessii*. (Gymnoascaceae).

*Myxotrichum emmonsii* Kuehn, Mycologia **47**:539, 1955
=*Auxarthron umbrinum*. (Onygenaceae).

*Myxotrichum foliicolum* Niessl Nova Hedwigia **17**:176, 1878 Nom. Nud. ex Saccardo, Saccardo, Sylloge Fungorum **4**:319, 1886
=*Cladotrichum folliicolum* (Niessl) Ferro *fide* Ferro, Nuov. Giorn. Bot. Ital. II. **14** :228, 1907 (hyphomycete).

*Myxotrichum herbariense* (Orr and Kuehn) Apinis, Mycol. Pap. **96**:22, 1964
=*Tripedotrichum herbariense* Orr and Kuehn Mycologia **56**:483, 1964 ( *Species incertis est*.)

*Myxotrichum ochraceum* var. *stipitatum* (Lindfors) Apinis, 1964
=*Myxotrichum stipitatum*.

*Myxotrichum poluninii* Apinis, Mycol. Pap. **96**:22 FIG 1, 2, 4a-h, PL III
=*Myxotrichum bicolor*.

*Myxotrichum resinae* Fries, Systema Mycologicum **3**:349, 1832
=*Racodium aterrimum* Ehrenberg *fide* Saccardo, Sylloge Fungorum **4**:320, 1886.
=*Alysidium resinae* (Fries) M. B. Ellis, 1971 (hyphomycete).

*Myxotrichum spinosum* Massee and Salmon, Ann. Bot. **16**:64, 1902
=*Myxotrichum cancellatum*.

*Myxotrichum thaxteri* Kuehn, Mycologia **47**:878, 1955
=*Auxarthron umbrinum*. (Onygenaceae).

*Myxotrichum uncinatum* (Eidam) Schroeter, KryptogamenFlora von Schlesiens **3**:212, 1893
=*Uncinocarpus uncinatus*. (Onygenaceae).

## **PSEUDOGYMNOASCUS** Raillo, 1929

Zentralbl. Bakteriol. Paraditkde (Abth.2) **78**:520.

**Type species:** *Pseudogymnoascus roseus* Raillo.

**Ascomata:** yellow or rose, globose, discrete or confluent. **Ascospores:** hyaline, pale yellow or pink, fusiform, smooth. **Asci:** globose to ovoid. **Peridial hyphae:** slightly thick-walled, smooth or asperulate, swollen at the nodes (points of branching and anastomoses), some free ends terminating in roughened, clavate

cells. **Appendages:** not distinct, thin-walled, echinulate, or covered with warts, branches lacking. **Ascocarp initials:** ascomatal initials consisting of coiled ascogonia without a recognizable antheridium. **Anamorph:** aleurioconidia and arthroconidia in *Geomyces*.

**Notes:** Apinis (1964) considered this genus as a subgenus of *Gymnoascus*. The two are distinct enough to warrant not only their placement in different genera (based on ascospore morphology), but in different families. Close relationship was implied by the similarities in structure and color of the reticuloperidium. Von Arx (1981a) states that "the genera *Byssoascus*, *Pseudogymnoascus*, and *Myxotrichum* are related to *Neurospora* and *Faurelina*," but does not provide a discussion of this suggested relationship.

*Pseudogymnoascus roseus* Raillo, 1929 Zentrabl. Bakteriol. Parasitkde 78:515 FIG 2.

FIG 6.2, PL 6.2a

**Type material:** unknown.

≡*Gymnoascus roseus* (Raillo) Apinis, Mycol. Pap. **96**:8, 1964.

=*Gymnoascus rhousiogongylinus* Wener and Cain, Can. J. Bot. **48**:325, 1970.

=*Pseudogymnoascus vinaceus* Raillo, *loc. cit.*

≡*Gymnoascus vinaceus* (Raillo) Apinis, Mycol. Pap. **96**:9, 1964.

=*Pseudogymnoascus bhattii* Samson, Acta Bot. Neerl. **21**:519, 1972.

**Anamorph name:** *Geomyces* state of *Pseudogymnoascus roseus*, *fide* Sigler and Carmichael, 1976.

**Ascomata:** white at first becoming pinkish brown or rose to reddish brown, globose, 100-300$\mu$m diam., single or in clusters. **Ascospores:** off-white at first, becoming pink or brown, yellow or yellow-brown, smooth-walled ±fusiform, 1.7-2.1 x 2.9-3.7$\mu$m. **Asci:** globose, subglobose, 6.5-9.0 x 4.0-7.0$\mu$m. **Peridial hyphae:** slightly thick-walled, rough or finely granular, branched, anastomosed, nodes swollen. **Appendages:** short, thin-walled, unbranched, echinulate or warty. **Anamorph:** aleurioconidia and arthroconidia minutely roughened, hyaline or very pale pink to brown; on dendritic conidiophores. **In culture:** [UAMH 1644]. CER 21/25°C rose-colored, flocculent mounded hyphae, orange rim; reverse deep

reddish orange to brown. DSA 36/25°C white or very faint rose, felt-like; reverse yellow.

**Notes:** Raillo (1929) originally distinguished this genus from *Gymnoascus* based on basis of the structure of the peridium. Apinis (1964) placed the *Pseudogymnoascus* in synonymy with *Gymnoascus*. Samson (1972) pointed out that a more substantial reason for maintaining *Pseudogymnoascus* as a distinct genus was the fusoid shape of the ascospores. Also, unlike *Gymnoascus*, *Pseudogymnoascus* has an anamorph. Tsuneda (1982) presents a SEM study of this species.

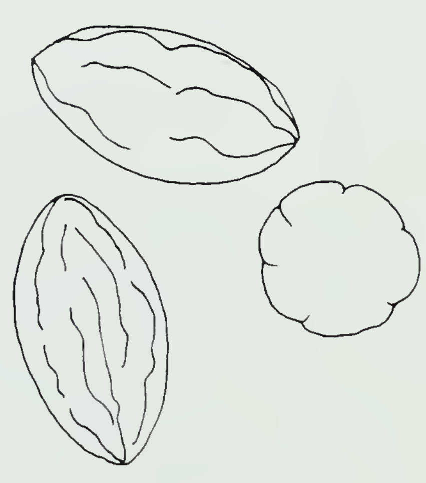
**Material examined: DAOM** 66374/spruce roots /Saskatchewan; 170480, 170481, 170482/soil/Alberta; **NY** O-1116, O-1146, O-3389/alpine soil/Alberta; O-3595/forest soil/Alberta; O-3729/porcupine dung/Alberta; **RSA**, 1966/mouse dung/California; **TRTC** 45536/soil/Ontario; 45538/porcupine dung/Ontario; **UAMH** 1644/larch wood/Italy from Kuehn (1963) (obtained by Kuehn from Dal Vesco); 4055/oil soaked soil/Northwest Territories; as *Pseudogymnoascus bhattii*: **NY** O-1119/alpine soil/Alberta (holotype strain).

Figure 6.1. *Myxotrichum deflexum* (LE Rabenhorst 2464).

**a** Ascoma with long, tapering appendages with deflexed branches. X375.

**b** Fusiform, striate ascospores. X6000.

a



b

Figure 6.2. *Pseudogymnoascus roseus* (RSA 1966).

a Ascoma with slightly thick-walled, branched and anastomosed, thick-walled peridial hyphae; nodal areas swollen; appendages echinulate. X830.

b *Geomyces* state showing dendritic conidiophore. X700.

c Smooth, fusiform ascospores. X7715.

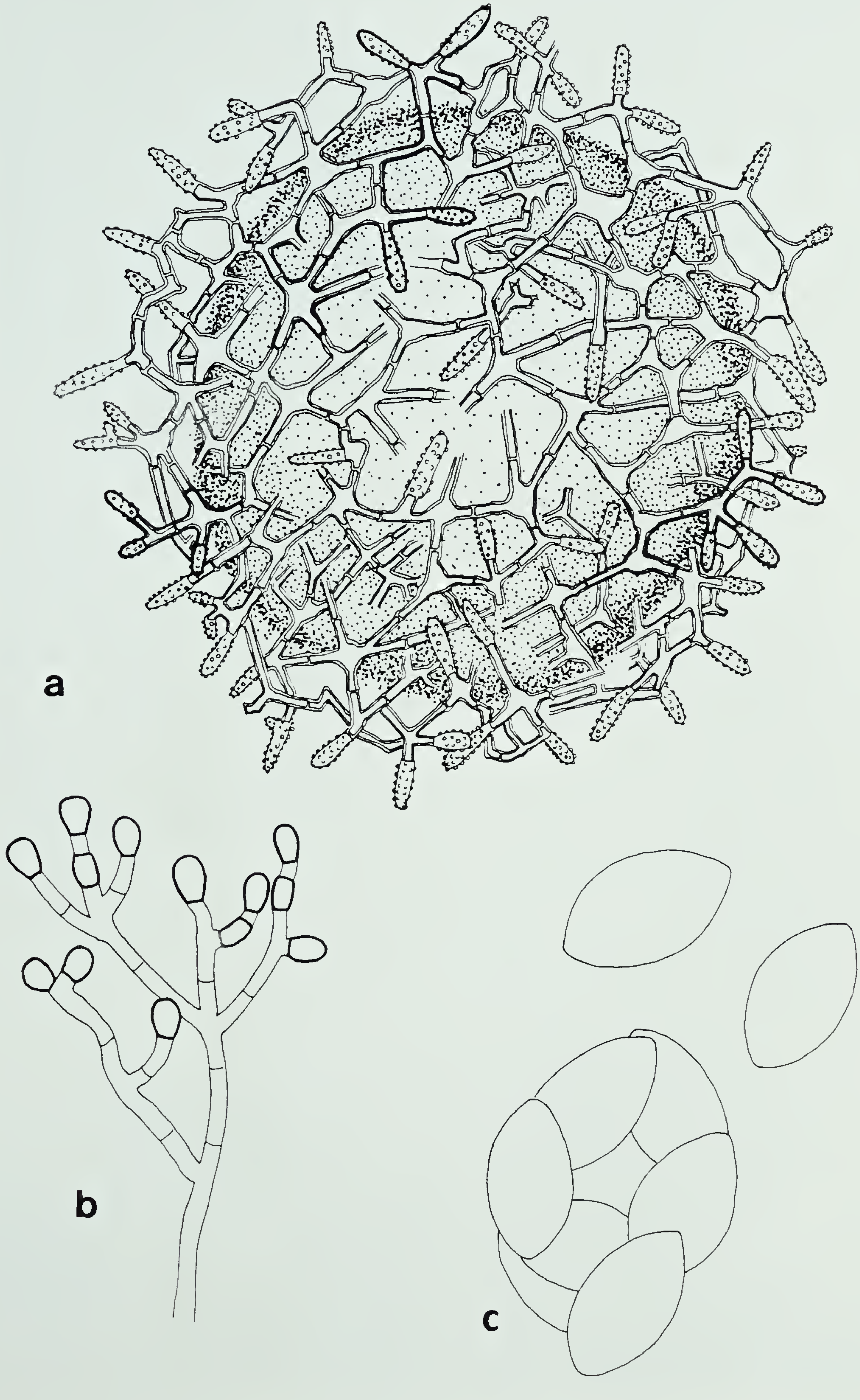

a
b
c

Plate 6.1.

**a** *Myxotrichum chartarum* (DAOM 49095). Richly branched reticuloperidium with uncinate appendages. X170

**b** *Myxotrichum bicolor* (LE NR26/511). Thick-walled, recurving peridial hyphae from confluent mass of ascomata. X300.

**c** *Myxotrichum cancellatum* (OSC 7282). Ascoma with long, radiating, spine-like appendages arising from the arches of the peridium. X200.

**d** *Myxotrichum ochraceum* (RSA 1190). Ascoma with long tapering appendages branched at base. X200.

**e** *Myxotrichum deflexum* (RSA 203). Ascomata with long, monopodially branched appendages. Apices acute. Side branches deflexed. X15

**f** *Gyrothrix podosperma* (LE 1866). Setae of this hyphomycete resemble the peridial hyphae of *Myxotrichum bicolor*. X120

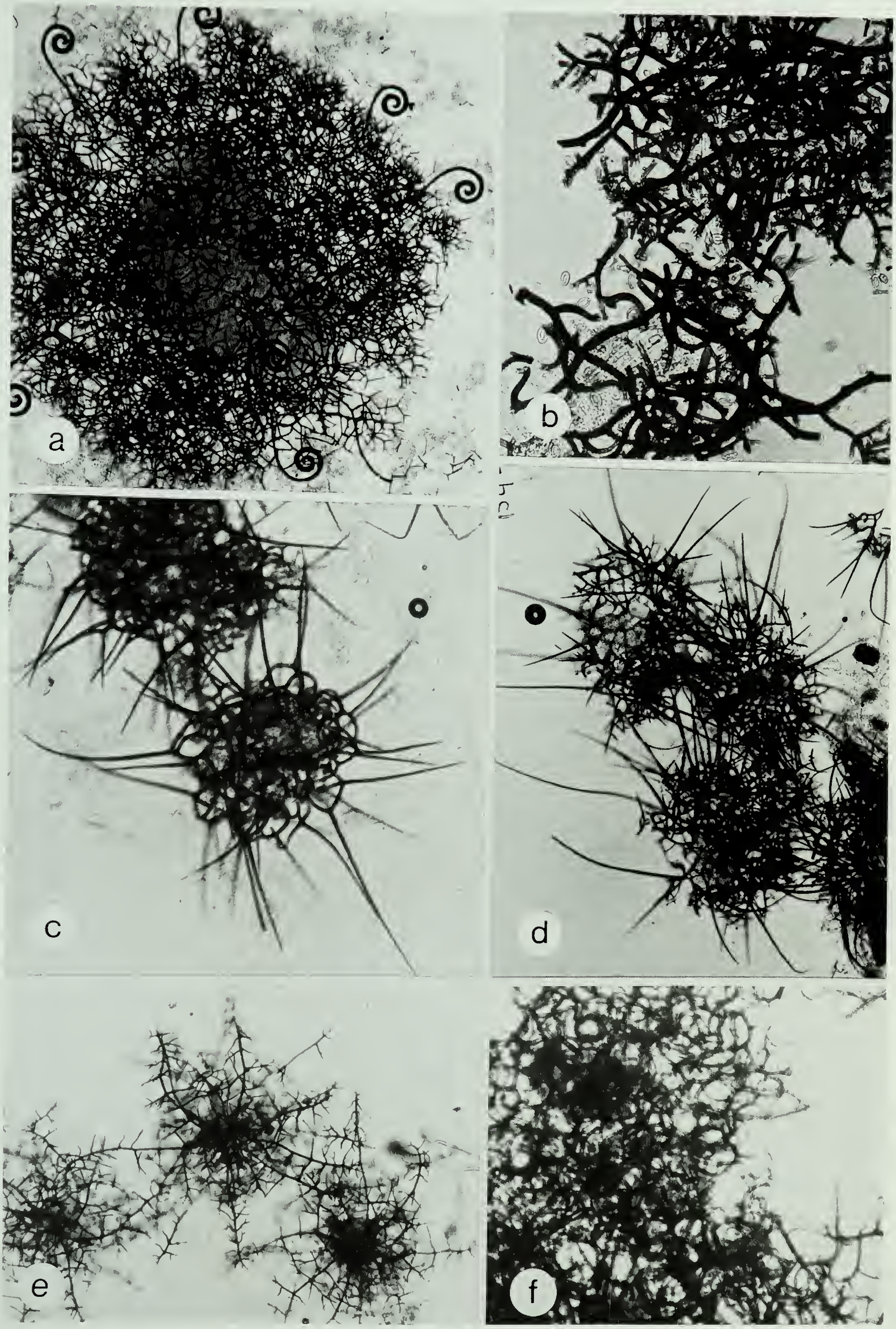

a
b
c
d
e
f

Plate 6.2.

**a** *Pseudogymnoascus roseus* (RSA 1966). Coarsely asperulate appendage. X1000.

**b** *Myxotrichum stipitatum* (RSA 1556). Three interlocked ascomata with typical sharp-spined peridial hyphae/appendages. X250.

**c** *Myxotrichum chartarum* (PAV 192). Habit on paper. X100.

**d** *Myxotrichum bicolor* (LE NR26/511). Element of the peridium. Arrow indicates "witches' broom" at proximal end of element. X250.

**e** *Myxotrichum chartarum* (PAV 192). Uncinate appendages slightly longer and less tightly coiled than those of DAOM 49095 (PL 6.1.a). X100.

**f** *Myxotrichum aeruginosum* (DAOM 50964). Elongate, uncinate appendages. X300.

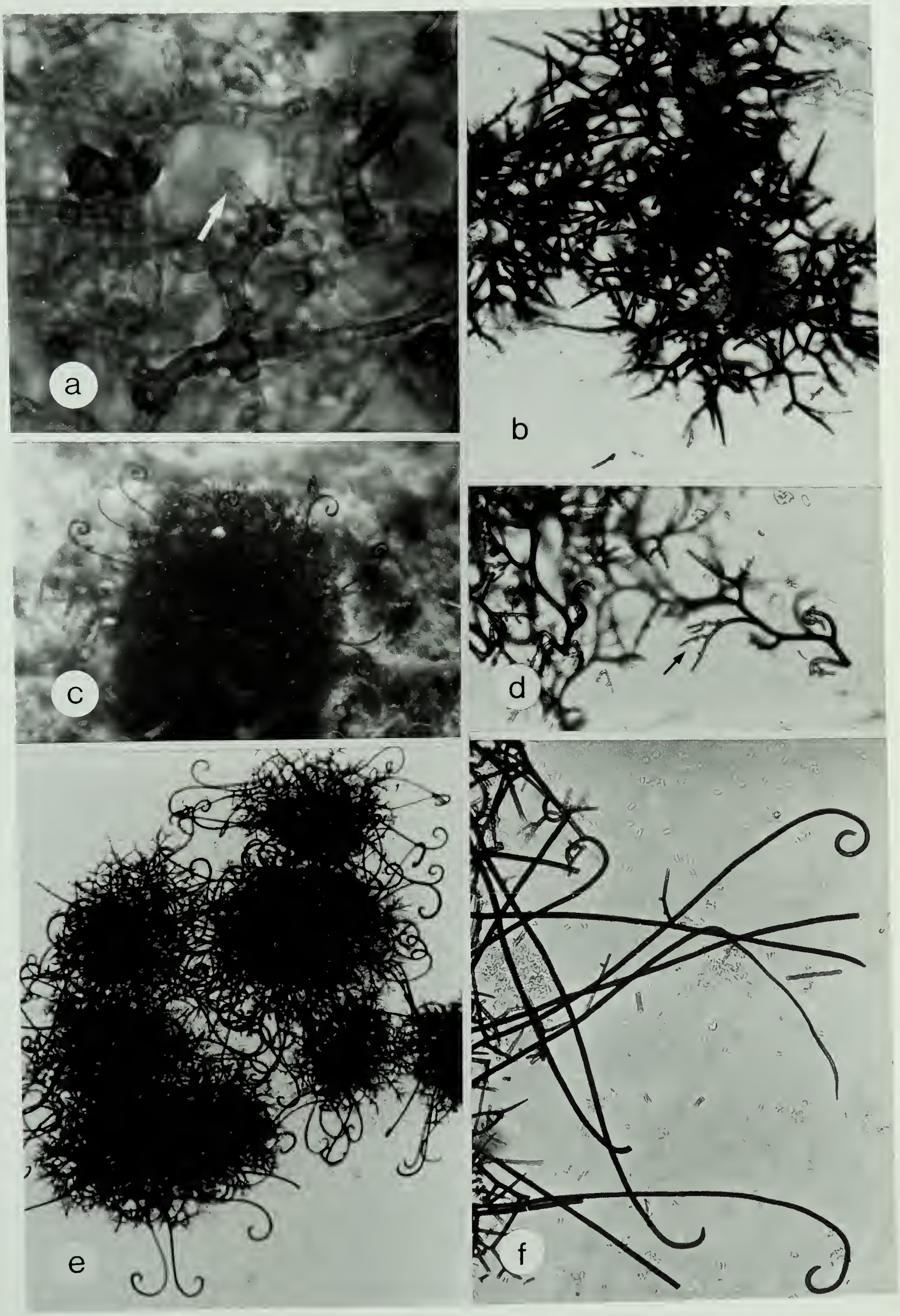

a
b
c
d
e
f

Plate 6.3.

**a** *Myxotrichum chartarum* (BR Zahlbruckner 3180). Fusiform ascospores with pronounced, longitudinal striae. X14000.

**b** *Myxotrichum stipitatum* (UAMH 3165). Ascospore with faint longitudinal striae. X26000.

**c** *Myxotrichum bicolor* (LE NR26/511). Ascospore with broadly rounded ends and regular, faint, longitudinal striae. X7750

**d** *Myxotrichum aeruginosum* (UAMH 3086). Longitudinally striate ascospore. X18000.


a
b
c
d

# CHAPTER 7

## ONYGENACEAE

Onygenaceae Fries, 1849 Summ. Veg. Scand. 2:446.

Type genus: *Onygena* Persoon

**Ascomata:** white to light-colored, or in shades of reddish brown; globose when discrete and <1000$\mu$m diam., but often confluent and sometimes stromatic forming compound structures up to several cm in diam. **Ascospores:** hyaline to pale yellow or reddish brown, spherical or oblate, allantoid in several genera, walls always punctate to punctate-reticulate, ridges of puncta broad and smooth, or narrow and ragged giving a spiny appearance; often appearing almost smooth with the light microscope; usually <6$\mu$m diam. **Asci:** ±globose or broadly clavate. **Peridial hyphae:** lacking or ±present in which case they may be: 1. undifferentiated from vegetative hyphae (telaperidium); or 2. thick-walled, tubular cells (reticuloperidium); or 3. thick-walled irregular cells which disarticulate (incompositothecium); or 4. flattened and membranous forming a cleistoperidium; **Appendages:** lacking or well-developed, frequently crozier-like. thin-walled helices occasionally formed. **Thallism:** heterothallic or homothallic. **Anamorph:** conidia with rhexolytic dehiscence; in genera *Chrysosporium*, *Malbranchea* or *Sporendonema*. **Degrades:** keratin (or nitrogenous compounds of animal origin).

**Notes:** The Onygenaceae consists of a relatively homogeneous group of genera with three prominent characteristics: rhexolytically dehiscing conidia, punctate ascospores, and the ability to break down keratin. The family is close to the smooth-spored Arthrodermataceae which also has rhexolytically dehiscing conidia and keratinolytic capabilities. Single-celled arthroconidia predominate in the Onygenaceae while non-septate to multiseptate aleurioconidia predominate in the Arthrodermataceae. Two sizes of conidia are formed in both families. In the Onygenaceae, *Renispora* and *Ajellomyces* both produce large, globose, spiny conidia. Many of the Arthrodermataceae also form large ornamented conidia which may be either multiseptate (e.g. *Microsporum canis*) or nonseptate (e.g. *Chrysosporium* state of *Ctenomyces serratus*).

The potent pathogen, *Coccidioides immitis*, has an anamorph of alternate arthroconidia, and also causes a deep mycosis like *Ajellomyces*, rather than

superficial ones, like the pathogenic members of the Arthrodermataceae. It has never been known to form a sexual state either *in vitro* or *in vivo*. Spherules which propagate the fungus in tissue by the formation of endospores have been sectioned at many different stages of development. Synaptonemal complexes have not been found, indicating that the spherule stage is not the site of meiotic events (personal communication, Cole, 1983). It is probable that this fungus will eventually be found to be a member of the Onygenaceae. The sexual stages of many parasitic fungi are often rare (e.g. *Ajellomyces*, *Filobasidiella*), and when formed have reduced structures accessory to meisopore production.

A different type of reduction has occurred in *Oncocladium flavum*. This keratinolytic fungus produces alternate arthroconidia in a mass of hyphae and thick-walled appendages that superficially resembles an ascoma. In fact, it was originally described as *Gymnoascus verticillatus* but there are no confirmed reports of ascospores being formed. An isolate which developed on coyote dung from southern Alberta produced characteristic appendaged ascoma-like masses on sheep's wool but not on artificial media. This suggests that this fungus (and probably other Onygenales) has specific nutritional requirements which affect morphogenetic processes. A similar event occurred with *Onygena* species grown on artificial media and on sterilized horse hoof. Growth on hoof demonstrated large, stipitate, sterile structures while isolates on agar grew more or less appressed to the medium and did not form characteristic or distinctive structures.

In general, the habitat of the Onygenales is dung and soil enriched with keratin. Occasionally the less specialized taxa (e.g. *Aphanoascus*) may be found on herbivore dung, where the keratin source is probably hair ingested during grooming.

TABLE 7.1

GENERA OF ONYGENACEAE*

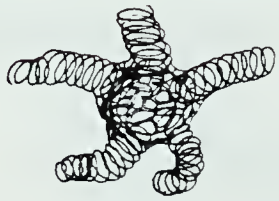
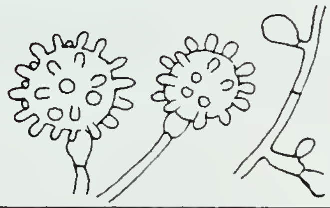
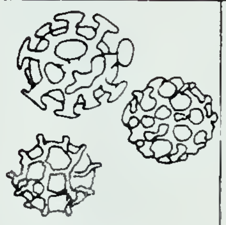
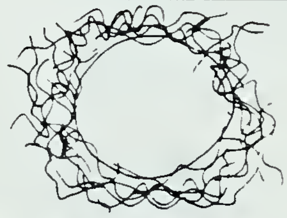
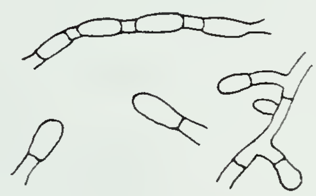
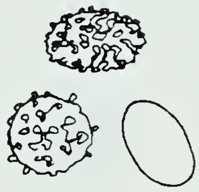
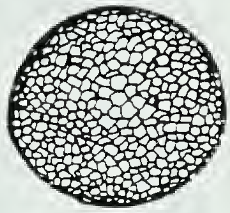
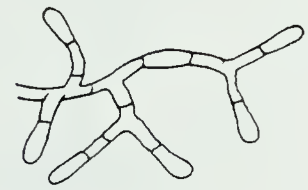
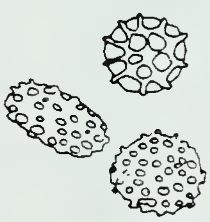
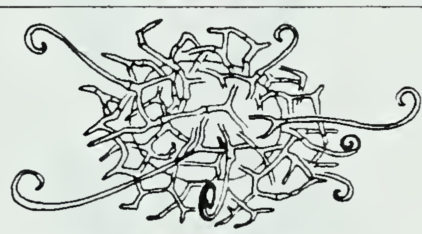
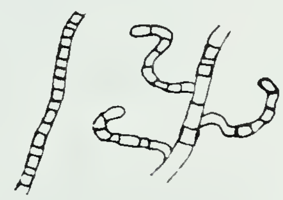
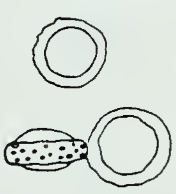
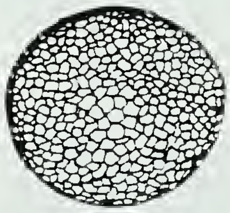
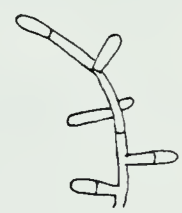
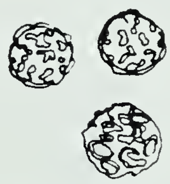
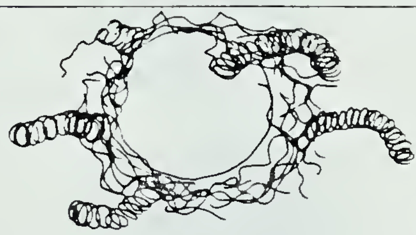
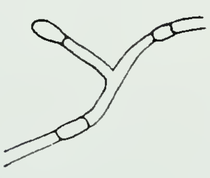
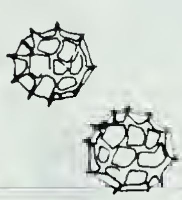
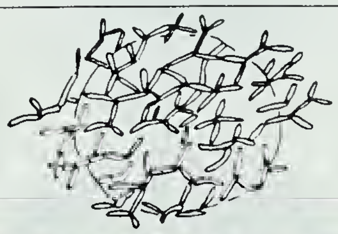
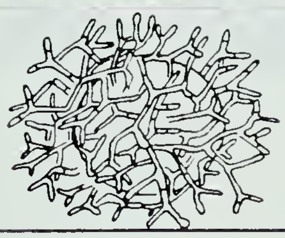
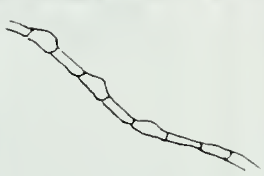
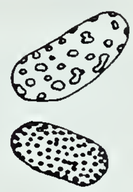
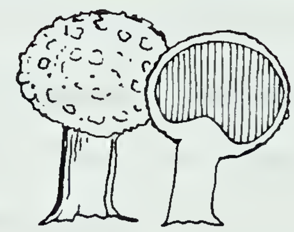
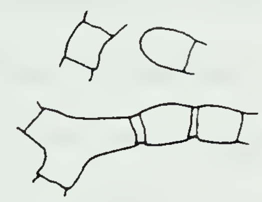
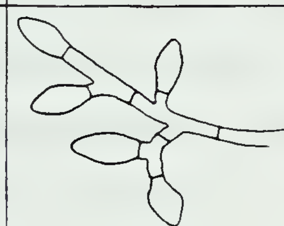
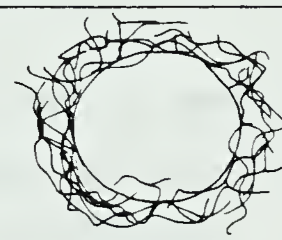
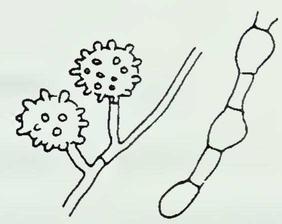
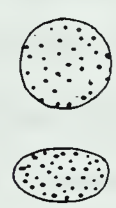
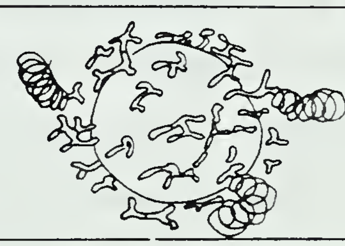
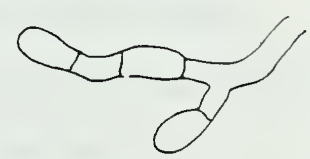
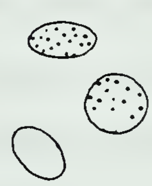
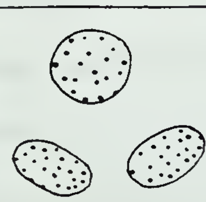
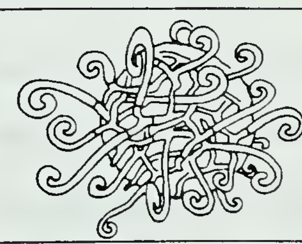
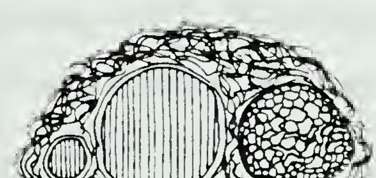
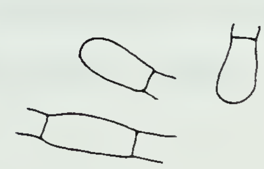
| Genus | Ascospores | Peridia and Appendages | Anamorphs |
|---|---|---|---|
| Ajellomyces |  |  |  |
| Amauroascus |  |  |  |
| Aphanoascus |  |  |  |
| Auxarthron |  |  |  |
| Keratinophyton |  |  |  |
| Kuehniella |  |  |  |
| Nannizziopsis |  |  |  |
| Neogymnomyces |  |  |  |

TABLE 7.1 (continued)

GENERA OF ONYGENACEAE*

| Genus | Ascospores | Peridia and Appendages | Anamorphs |
|---|---|---|---|
| Onygena |  |  |  |
| Pectinotrichum |  |  |  |
| Renispora |  |  |  |
| Shanorella |  |  |  |
| Spiromastix |  |  | ? |
| Uncinocarpus |  |  |  |
| Xynophila |  |  |  |

*Apinisia, Ascocalvatia and Neoxenophila not figured.

**AJELLOMYCES** McDonough and Lewis, 1968, em. McGinnis and Katz, 1979 (Mycologia **60**:76) Mycotaxon **8**:157.

**Type species:** *Ajellomyces dermatitidis* McDonough and Lewis.

=*Emmonsiella* Kwon-Chung, 1972.

**Ascomata:** tan, globose to stellate, to 350um diam. **Ascospores:** hyaline, globose, minute, <2.0um diam.; TEM has shown puncta on the ascospore wall. **Asci:** subglobose, clavate to pyriform, 8-spored. **Peridial hyphae:** thin-walled, branching, constricted at septa and arising from the sides of coiled appendages. **Appendages:** thick-walled, septate helices arising from a common centre; inner walls thicker than outer walls. **Thallism:** heterothallic; gametangia of swollen cells of unequal size. **Anamorph:** aleurioconidia in hyphal phase; yeast-like state at 37°C. **Degrades:** not strongly keratinolytic, prefers complex nitrogenous materials.

**Notes:** Kwon-Chung (1973) distinguished the genus *Emmonsiella* from *Ajellomyces* on the basis of morphology of ascoma initials, shape and size of asci and peridial hyphae. McGinnis and Katz (1979), in a detailed re-examination of both taxa, determined that differences maintained by Kwon-Chung, either could not be entirely substantiated or were not sufficiently distinctive to merit a new genus. They placed *Emmonsiella* in synonymy with *Ajellomyces*. Differences between the two are sufficient at the species level. Both species of *Ajellomyces* are serious pathogens of humans. Although teleomorphs have never been found in nature, they may be observed by plating appropriate strains together on artificial media.

**References:** Emmons, Binford, Utz and Kwon-Chung, 1977. (Clinical and epidemiological discussion of diseases caused by the two species in the genus). Glick and Kwon-Chung, 1973 (TEM of ascospores of *Ajellomyces dermatitidis* and *Ajellomyces capsulatus*). Kwon-Chung, 1973. (Illustrated developmental study). Kwon-Chung, 1975. (Taxonomic status of species causing large-form African histoplasmosis).

*Ajellomyces capsulatus* (Kwon-Chung) McGinnis and Katz, 1979 Mycotaxon **8**:157.

**Type material:** HOLOTYPE (*cultura desiccata*) **BPI** 71811.

≡*Emmonsiella capsulata* Kwon-Chung, Science **177**:368, 1972 **Anamorph names:** *Histoplasma capsulatum* Darling (1906), was applied to the yeast phase. Carmichael (1962) included the conidial phase in *Chrysosporium*. (Detailed lists of synonyms of the anamorph name used here may be found in De Vries, 1983).

**Ascomata:** yellowish tan, globose to subglobose, 80-250*um*. **Ascospores:** hyaline, globose, smooth, (TEM shows regular puncta of walls), 1.2-1.5*um* diam. **Asci:** subglobose, clavate to pyriform, to 7.0*um* maximum. **Peridial hyphae:** swollen, thin-walled, sinuous hyphae developing from helical appendages, anastomosing and branching dichotomously, not swelling between septa (walls remain parallel). **Appendages:** cream to pale tan, thick-walled helices, 1.7-3.0*um* diam., originating from centre of ascoma , 30-100*um* long; (2)3-5(10) per ascoma. **Anamorph:** Microconidia globose or pyriform, smooth, spiny or finely roughened, 2.0-6.0*um* diam., sessile or on short, narrow (rarely inflated) conidiophores which develop at right angles from parent hyphae. Macroconidia spherical, (rarely pyriform), ornamented with broad spines; 8-14*um* diam., borne in the same manner as the microconidia. **In culture:** at 30°C and lower: white, downy at first, becoming buff to brown; resembling *Ajellomyces dermatitidis*, but having a slower growth rate. Grows as a yeast at 37°C.

**Notes:** Causative agent of systemic mycosis (Histoplasmosis, Darling's disease, reticuloendothelial cytomycosis, reticuloendotheliosis) (Emmons *et al.*, 1977). In tissue (and in culture at 37°C) this fungus forms a yeast-like state of oval cells, 2-3 x 3-4*um*, which bud at narrow ends through very narrow (0.2-0.3*um* diam.) pores. Found throughout the tropical and temperate parts of the new world in areas with red-yellow, podzolic soils, especially if enriched with bat or bird dung.

*Ajellomyces dermatitidis* McDonough and Lewis, 1968 Mycologia **60**:77 FIG 1-6.

FIG 7.1

**Type material:** HOLOTYPE (*cultura desiccata*) **CDC** (human isolates, North America?).

**Anamorph name:** *Chrysosporium dermatitidis* (Gilchrist and Stokes) Carmichael *fide* Carmichael, 1962 (Synonyms may be found in Carmichael *op. cit.*) (Yeast state in form-genus *Zymonema*).

**Ascomata:** tan, globose to subglobose, 200-350um diam. **Ascospores:** hyaline, globose, smooth, (TEM shows regular puncta), 1.3-1.6um. **Asci:** subglobose, clavate to pyriform, 3.8-7.5um diam. **Peridial hyphae:** pale brown or reddish brown, arising from coils, anastomosing and branching dichotomously, swelling between septa which are 0.25-1.5um diam.; cells 1.5-4.5 x 1.5-10.5um diam. **Appendages:** generally 3-5, thick-walled, helical hyphae, 2.3-7.5um diam., inner walls thickened. **Anamorph:** aleurioconidia solitary, globose or pyriform, smooth, sessile or pedicellate, lateral or terminal, 2-10um diam. **In culture:** mycelial at 30°C and lower: at first forming moist, ±synnematal aggregations with a variable amount of white or brownish aerial mycelium, and with or without a diffusible brown pigment.

**Notes:** At 37°C and in animal tissues, this fungus grows as globose, thick-walled yeast cells, 8-15um diam., with unipolar (occasionally bipolar) blastoconidia which are broadly attached to parent cell (4-5um at point of attachment). The mycosis caused by *Ajellomyces dermatitidis* is recorded from North and South America and Africa but the natural habitat of the fungus is unknown. It has been isolated from soil (rarely) (Emmons *et al.*, 1977).

**AMAUROASCUS** Schroeter, 1893

KryptogamenFlora von Schlesiens **3**:211.

**Type species:** *Amauroascus niger* Schroeter. (Lectotype *fide* Clements and Shear, 1931).

**Ascomata:** white, yellow, or brown, ±globose or ellipsoid, to 2.5mm in diameter. **Ascospores:** hyaline, yellow, or reddish brown to dark brown,

spherical, with a definite pattern of pronounced, irregular or regular puncta and ridges, 3.5-8.7$\mu m$ diam. **Asci:** ovoid, to 14$\mu m$ maximum, 8-spored. **Peridial hyphae:** usually undifferentiated in culture, but occasionally pale brown, ±smooth and thick-walled. **Appendages:** lacking. **Anamorph:** terminal and/or intercalary, rhexolytically dehiscing conidia. **Degrades:** keratin.

**Notes:** The genus *Amauroascus* was first erected by Schroeter to include species with small, spiny, brown or violet ascospores within a peridium of loosely interwoven, undifferentiated hyphae. Its relationship to *Arachniotus* (*sensu* Schroeter) was considered close (Benjamin, 1956; Kuehn, 1958), or congeneric (Orr and Varsavsky, 1965), until Von Arx (1971) distinguished the taxon on the basis of the spherical, ornamented ascospores. Von Arx, without explanation, designated the lectotype of the genus as *Amauroascus verrucosus* (=*Amauroascus mutatus* (Quelet) Rameloo q.v.). Clements and Shear (1931) and Benjamin (1956) had previously cited the lectotype as *Amauroascus niger* and according to article 8.1 (ICBN) this choice must be followed. Schroeter did not indicate which of the two taxa he had selected for type.

Von Arx transferred *Arachniotus aureus* and *Arachniotus albicans* (Apinis, 1964) to *Amauroascus* on the basis of spore shape and ornamentation. This move is substantiated by the keratinolytic abilities of the two taxa.

*Pseudoarachniotus echinulatus* Dutta and Ghosh (1963) was also transferred to *Amauroascus* by Von Arx, but I disagree with this disposition. This species is not keratinolytic. The ascospores possess prominent, blunt, cone-shaped spines rather than the puncta typical of *Amauroascus*. It does not have an anamorph. Consequently there is no reason to keep *Pseudoarachniotus echinulatus* in the Onygenales. Von Arx maintained that, on the basis of gametangial morphology, *Amauroascus* had a close relationship to *Narasimhella* (see *Gymnascella hyalinospora*), but I consider them very different and distantly related taxa.

*Amauroascus* is most closely related to *Auxarthron*. Both of these genera have markedly punctate ascospores. The distinction between the genera is not clear-cut, but the major features distinguishing *Amauroascus* from *Auxarthron* are the much larger puncta on the ascospore wall and the general absence of

differentiated peridial hyphae in *Amauroascus*. *Amauroascus kuehnii* and *Amauroascus pseudoreticulatus* represent species which are intermediate between the two genera, in that they have differentiated peridial hyphae which are similar to those of *Auxarthron*. Some reservation must be employed in differentiating these two genera on the basis of peridial hyphae, since the species are known in most detail on artificial culture media and there may be some limitations on their morphological expression in this environment. Clarification of the limits of the two genera requires more extensive work in collection and isolation of new strains, particularly of *Amauroascus*, which is quite rare.

Because there are so few isolates of representatives of this genus, statements about habitat are mostly speculative. Since, in culture, all isolates of the genus are keratinolytic, *Amauroascus* is probably a saprophyte of keratinous debris and soil is the most probable habitat. The isolation of *Amauroascus aureus* from wood is puzzling, although the presence of small amounts of keratin in the vicinity of the collection might have been overlooked.

None of the species of *Amauroascus* has been implicated as an animal pathogen.

*Amauroascus albicans* (Apinis) von Arx, 1971 Persoonia **6**:376.

PL 7.1e

**Type material**: HOLOTYPE (*cultura desiccata*). **CMI** (=BDUN 264) (soil, England).

≡*Arachniotus albicans* Apinis, Mycol. Pap. **96**:45, 1964 PL III FIG 10 a-m (Basionym).

**Ascomata:** white or cream, globose, 0.3-1.0(2.0)mm, single or in clusters. **Ascospores:** hyaline, globose to subglobose, punctate-reticulate, 3.0-4.5(-5.0)µm. **Asci:** ovoid, 8.0-11 x 11-17µm. **Peridial hyphae:** hyaline, undifferentiated, delicate, loosely interwoven. **Anamorph:** conidia hyaline, solitary, smooth, pyriform, one-celled, 3.5-4.5(-6.5) x 4.5-7.5µm. **In culture:** [UAMH 3102]. CER 42/25°C white, wispy to felty mat with pale yellow knots. DSA 49/25°C pale yellow, granular, scant. PYE 42/25°C dense felty white; reverse orange-brown.

**Material examined:** as *Arachniotus albicans*: **UAMH** type strain as cited;

from Orr; **NY** 0-3220/Soil/Germany (Utah?).

*Amauroascus aureus* (Eidam) von Arx, 1971 Persoonia **6**:375.

<u>PL 7.1d</u>

**Type material:** NEOTYPE (?) **RSA** 1532 (decayed wood of *Cryptomeria japonica*, Japan).

=*Gymnoascus aureus* Eidam, Ber. Bot. Sect. Schles. Ges. **64**:161, 1887 (Basionym).

=*Arachniotus aureus* (Eidam) Schroeter, KryptogamenFlora von Schlesiens **3**:210, 1893.

**Ascomata:** shades of yellow, usually discrete, ±spherical, 300-1000*um* and/or naked clusters of asci, 70-350*um*. **Ascospores:** hyaline to pale yellow, yellow in mass, 3.3-5.5*um* diam., punctate-reticulate, conglobate. **Asci:** globose, subglobose or ellipsoidal, 9-13*um* diam. **Peridial hyphae:** 1. yellow, smooth, thin-walled, septate, branched, rather straight, 2.0-4.4*um* diam.; and 2. branching, sinuate hyphae, 2.0-2.2*um* diam. **Anamorph:** conidia long, narrow, 2.2 x 10*um*, often constricted at septa, clavate to elongate, hyaline, finely tuberculate, 3.3-7.0 x 5.5-20*um*, pedicellate or sessile, base narrow or broad, lateral, terminal or intercalary. *Chrysosporium* anamorph *fide* Kuehn, Tubaki and Orr, 1964. **In culture:** [UAMH 3157]. CER 21/25°C bright lemon-yellow, fluffy or felty, with a broad margin of hyaline hyphae; reverse light yellow. DSA 42/25°C hyaline with numerous cottony, citrine yellow, pulvinate masses; reverse yellow. PYE 35/25°C brilliant yellow, thick-felty, granular; reverse brownish yellow.

**Material examined:** as *Arachniotus aureus*: **RSA** (neotype as cited) (=UAMH 3157); **NY** Brandsberg Mo-32/soil/Missouri (dried culture); as *Arachniotus* sp.; **UPS** Bjorkman/wood of the 'Vasa'/Sweden, (dried culture).

*Amauroascus kuehnii* Von Arx, 1971 Persoonia **6**:376.

<u>PL 7.1e, 7.2c,d</u>

**Type material:** TYPE STRAIN **UAMH** 3 (bat dung dust, Georgia).

=*Arachniotus reticulatus* Kuehn, Mycologia **49**:57, 1957 FIG 1-18, 31.

Non *Amauroascus reticulatus* (Kuehn and Goos) Von Arx, 1971 (see notes

under *Amauroascus pseudoreticulatus*).

**Ascomata:** yellow to brown at maturity, 130-900um diam. **Ascospores:** pale yellowish brown, punctate-reticulate, 3.5-4.2um diam. **Asci:** hyaline, oblong, 7.0-8.4 x 11.2-12.6um. **Peridial hyphae:** hyaline, thin-walled and scarcely differentiated, and some moderately thick-walled, brown, faintly tuberculate, branched and anastomosed. **Anamorph:** smooth, hyaline, intercalary conidia, 2.0-4.0 x 2.8-8.4um. **In culture:**[UAMH 3]. CER 21/25°C white to pale ochre, cottony becoming granular in older portions; reverse uncolored. DSA 28/25°C ochre brown with knots of dark brown in the vicinity of hair; reverse uncolored. PYE 35/25°C yellow, dense, felty, purplish brown toward centre, margin white; reverse buff tan.

**Notes:** Von Arx changed the species epithet since "reticulatus" was already occupied in *Amauroascus* (but see notes under *Amauroascus pseudoreticulatus*). *Amauroascus kuehnii* is similar to *Amauroascus volatilis-patellis* but has shallower puncta on the ascospore walls.

**Material examined: RSA** 403/dung/California; 1253/dung/Arizona; 1254, 1505/mouse dung/California; 1439, 1478/lizard dung/Mexico; **UAMH** 3 (type strain as cited).

*Amauroascus mutatus* (Quelet) Rammeloo, 1982 Bull. Jard. Bot. Nat. Belg. **52**:241-243 FIG 1-6.

PL 7.1a

**Type material:** LECTOTYPE (natural material). **UPS** Bresadola (hair filled material, France). (*fide* Rammeloo 1982).

=*Onygena mutata* Quelet, Mem. Soc. Emul. Montbeliard **5**:449, 1875. (Basionym).

=*Gymnoascus verrucosus* Eidam, Ber. Bot. Schles. Ges. **64**:162, 1886. (cited in Rammeloo, *op. cit.*).

=*Amauroascus verrucosus* (Eidam) Schroeter, KryptogamenFlora von Schlesiens **3**:211, 1893.

=*Arachniotus verrucosus* (Eidam) Kuehn, Orr and Varsavsky, Mycopathol. et Mycol. Appl. **25**:103, 1965.

**Ascomata**: white, becoming brown, spherical, 0.8-6.0mm, diam. **Ascospores**: brownish at maturity, punctate-reticulate with prominent capitate spines up to 1.0*um* in length and resembling "hoodoos"; 6.0-8.7*um* diam. including spines. **Asci**: 15-17 x 18-24*um*, 8-spored. **Peridial hyphae**: in culture not distinctive, hyaline, thin-walled, smooth, 2.0-3.3*um* diam.; in nature forming a crust-like covering on surface of ascomata. **Anamorph**: arthroconidia, 1.4-2.6 x 5.3-19.0*um*. **In culture**: [UAMH 3576]. CER 42/25°C white, subcottony, thin. DSA 42/25°C white, dusty. PYE 42/25°C white with pale yellow areas (indicating "pockets" of ascospores); reverse orange to yellow orange.

**Notes**: Recorded from: rotten leather boot, Germany (Eidam, 1887); decaying feathers, France (Dangeard, 1907); soil, England (Apinis, 1964); Germany, Argentina (Orr *et al.*); soil/dung, Belgium, Argentina and Italy (Ajello *et al.*, 1965).

**Material examined: UPS** (type as cited); **NY** P 526/soil/Oklahoma (=UAMH 3576); O-3162/soil/California.

*Amauroascus niger* Schroeter, 1893 KryptogamenFlora von Schlesiens **3**:211.

7.1c, 7.20a

**Type material**: NEOTYPE STRAIN **UAMH** 3544 (soil, California).

≡*Arachniotus niger* (Schroeter) Kuehn *et al.*, Mycopathol. et Mycol. Appl. **25** :106, 1965.

**Ascomata**: red-brown to grayish brown when mature, discrete, globose, 0.5-2.5mm. **Ascospores**: red-brown, black in mass, thick-walled, globose, irregularly punctate-reticulate, 4-6*um* diam. **Asci**: ellipsoid, 10-12 x 11-14*um*. **Peridial hyphae**: barely differentiated when young, becoming thicker and pale brown with age, 2.0-3.0*um* diam. **Anamorph**: irregular arthroconidia in vicinity of ascospore production, 1.5-2.2 x 10-15*um*. **In culture**: [UAMH 3544]. CER 35/25°C numerous dark brown tuberculate tufts over hyaline mycelium. DSA 42/25°C yellow to reddish tan, floccose around hair. PYE 42/25°C grayish yellow, dense-felty mat; reverse grayish.

**Notes**: Apinis (1964) did not deal with this taxon since it was known only from Germany and USSR. Orr described the spores as "globose with a fluted

rim."

**Material examined:** UAMH 3544 (neotype strain as cited).

*Amauroascus pseudoreticulatus sp. nov.*

*Typus: HOLOTYPUS* **UAMH** *3117 (cultura desiccata "OAT") (fimo lacerti, Mexicensis)*

*Ascocarpi ochracei aut olivacei, discreti, globosi, 80-1600um. Ascosporae aureae, globosi, murae incrassatae, reticulato-venosae, 4.5-6.0um. Asci globosi, 8.5-9.0.um Hyphae peridii ochraceae, murae incrassatae, tuberculatae, constrictia ad septi, 3.5-6.0um. Stat. conid. absens. In cultura: CER 35/25°C mycelia aureo-rubiginosa caespitosa, reverso brunneo; OAT ascocarpi ochracei abundans.*

*Amauroascus pseudoreticulatus* sp. nov. .

PL 7.2b

**Type material:** HOLOTYPE **UAMH** 3117 (*cultura desiccata*) (on OAT) (lizard dung, Mexico).

**Ascomata:** ochre to olive, discrete, globose, 80-1600*um*. **Ascospores:** golden yellow, globose, thick-walled, regularly punctate-reticulate, 5.0-6.0*um* diam. **Asci:** ±globose, 8.5-9.0*um*. **Peridial hyphae:** ochre, tuberculate, thick-walled, constricted at septa. **Anamorph:** lacking. **In culture:** [UAMH 3117]. CER 35/25°C bright rusty yellow with many discrete tufts; reverse brown. DSA 42/25°C cinnamon brown with discrete globose tufts; reverse concolorous or slightly darker. PYE 42/25°C fawn yellow, slightly cottony to granular; reverse reddish brown.

**Notes:** This taxon is described to accommodate two isolates which have been misidentified as *Amauroascus reticulatus* (Kuehn and Goos) Von Arx (1971). The type of *A. reticulatus* was isolated from the rhizosphere of *Musa sapientium* and has sheathed ascospores which closely resemble those of *Amauroascus* in size. (see PL 7.4d). Since *A. reticulatus* does not attack keratin, it is excluded from the family. The sheathed ascospores exclude it from the Onygenales.

*A. pseudoreticulatus* appears to be a species which is transitional between *Amauroascus* and *Auxarthron* due to nature of the ascospores and the presence

of differentiated peridial hyphae. The size of the ascospores, and the large puncta in the ascospore wall, indicate that this taxon is best considered in *Amauroascus* rather than in *Auxarthron*, in spite of the differentiation in the peridial hyphae.

**Material examined:** **RSA** 1426 (=UAMH 3117), 1502/lizard dung/Mexico.

*Amauroascus volatilis-patellis* Orr and Kuehn, comb. nov. .

PL 7.1b

**Type material:** HOLOTYPE **NY** DPG 140 (clay soil, Utah).

=*Arachniotus volatilis-patellis* Orr and Kuehn, Mycologia **64**:61, 1972 FIG 7-8 (Basionym).

**Ascomata:** white, globose, 270-550*um*, diam. **Ascospores:** hyaline, spherical, 5.0-6.0*um* diam., broadly punctate-reticulate. **Asci:** spherical, 12-16*um* diam. **Peridial hyphae:** hyaline, 1.9-3.8*um* wide, undifferentiated. **Appendages:** lacking. **Anamorph:** hyaline, subspherical to clavate, terminal conidia 2.0-3.0 x 4.3-5.2*um*, and cylindrical, intercalary conidia, 2.0-2.7 x 4.0-5.4*um*. **In culture:** [UAMH 3406]. CER 35/25°C yellowish orange, glabrous in central region, hyphal mat mostly white, thin; reverse tan-yellow. DSA 42/25°C pure white, granular; reverse uncolored. PYE 49/25°C citrine yellow in centre; reverse deep reddish brown.

**Notes:** Ascospore morphology was misinterpreted in Orr and Kuehn's original description. The puncta are exceptionally deep and broad, giving the perimeter of the ascospores an opaque quality which differs substantially from the central region overlying the core. Orr and Kuehn described the perimeter as a "scalloped marginal band" resulting in a comparison of the ascospores to "flying saucers."

**Material examined:** **NY** (type as cited), (=UAMH 3406 from Orr).

## **APHANOASCUS** Zukal, 1890

Ber. Deut. Bot. Ges. **8**:296.

**Type species:** *Aphanoascus fulvescens* (Cooke) Apinis.

=*Anixiopsis* Hansen, 1897.

**Ascomata**: yellow-brown to dark brown, ±globose, 100-400$\mu m$ diam. **Ascospores**: yellow-brown, ±oblate, with numerous, minute, irregular puncta, 5.0-8.5 x 4.0-5.5$\mu m$. **Asci**: ±globose, thin-walled, 8-spored. **Appendages**: lacking. **Peridial hyphae**: reddish brown, several layers of flattened cells forming a membrane; outer layer thick-walled. **Ascocarp initials**: Homothallic. Subglobose to slightly elongated and curved ascogonia; slender hyphae growing out from the basal cell develop closely attached to the ascogonial cell and branch to form the peridium Domsch, Gams and Anderson (1980). **Anamorph**: *Chrysosporium*. **Degrades**: keratin.

**Notes**: The nomenclature of this genus has been clarified by Apinis (1968). The same fungus had been described on three separate occasions in less than 30 years. The type species of *Aphanoascus* was first described by Cooke as a member of the myxomycete genus *Badhamia* (1875). Realizing that the fungus was an ascomycete, he then transferred the species to *Eurotium* in 1879. Hansen (1897) independently described the new ascomycete genus *Anixiopsis* on the basis of an isolate he labelled *Anixiopsis stercorarius* from fox dung. Zukal (1890) described *Aphanoascus cinnabarinus* from alligator dung. Apinis, after examining the type material of the three names took Cooke's species epithet and combined it with the genus name *Aphanoascus*, because of its obvious differences from *Eurotium*.

De Vries (1969) felt that ascospore size and ornamentation differed between *Anixiopsis* and *Aphanoascus* and recognized this at the variety level. After examining over 40 collections, I feel that distinction at this level is unwarranted. The complex pattern of puncta of the ascospore walls, and the often misinterpreted, oblate shape have given rise to confusion in this taxon. Apinis placed the genus (with *Keratinophyton*, which he considered a synonym) in the Cephalothecaceae, presumably on the basis of the membranous peridium. This family has penicillate phialoconidia and is not appropriate for these taxa. Malloch (1981b) placed the genus in the Onygenaceae.

Udagawa and Takada (1973) neotypified Zukal's name *Aphanoascus cinnabarinus* with a Eurotialean fungus which has a *Paecilomyces* anamorph and ascospores with dagger-like spines (see PL 7.20d). On the basis of this

neotype, Benny and Kimbrough (1980) placed *Aphanoascus* in the Trichocomataceae. Since these features differ from Zukal's protologue, and since Zukal's type is available (Apinis, 1968), Udagawa and Takada's neotype cannot be accepted.

*Aphanoascus canadensis sp. nov.*

*Typus: HOLOTYPUS (cultura desiccata)* **UAMH** *4574 (fimo carnivora, Albertensis).*

*Ascocarpi ferruginei, globosi, <800um. Ascosporae luteae, levae aut cum foveis minutis, oblatae, 2.5-3.1 x 3.8-4.2um. Asci globosi aut late ellipsoidi. Hyphae peridii membranaceae, cellulae irregularis, ferrugineae. Stat. conid. aleurioconidia et arthroconidia alterna, cylindracea, aliquando globosa 1.9-3.9 x 3.3-9.1um. In cultura: CER 38/25°C coloniis cum mycelio aerio sparso albo, pigmentum diffluens aurantiaco-tangerinum; reverso aurantiaco. OAT, ascoma i ferruginei abundans.*

*Aphanoascus canadensis* sp. nov. .

FIG 7.2, PL 7.8a,b

**Type material:** HOLOTYPE (*cultura desiccata*) **UAMH** 4574 (carnivore dung, Alberta).

**Ascomata:** reddish brown, globose, <800*um* diam. **Ascospores:** yellow, finely reticulate, oblate, 2.5-3.1 x 3.8-4.2*um*. **Asci:** globose to ellipsoid, 8.0-11*um* maximum. **Peridial hyphae:** membranous layer of irregular polygonal cells, some elongated. **Anamorph:** alternate arthroconidia and aleurioconidia, 1.9-3.9 x 3.3-9.1*um*; intercalary cylindrical conidia sometimes becoming globose. **In culture:** [UAMH 4574]. CER 38/25°C golden orange, tangerine, diffusible pigment with zonate aerial overgrowth of sparse hyaline mycelium; reverse orange. DSA 44/25°C hyaline white growth in the vicinity of hair; reverse uncolored. OAT 49/25°C abundant production of cleistothecia beneath cottony tomentum of vegetative hyphae. PYE 38/25°C cream to pale tan, deep cottony to felty; reverse pale yellowish tan.

**Notes:** This species is distinguished from *Aphanoascus fulvescens* on the basis of the finely sculptured ascospores, much smaller conidia, and the striking

differences exhibited in culture.

**Material examined: UAMH 4574** holotype as cited and type strain as cited.

*Aphanoascus fulvescens* (Cooke) Apinis, 1968 Mycopathol. et Mycol. Appl. **35**:101.

Fig 7.3, PL 7.3a,b,c,d,e,f, 7.20c

**Type material:** K M. C. Cooke ("*Badhamia fulvescens*, Dupplin, Perth, England." *fide* Apinis, 1968)

=*Badhamia fulvescens* Cooke, Grevillea **4**:9, 1875.

=*Eurotium fulvescens* (Cooke) Cooke, 1879.

=*Anixiopsis fulvescens* (Cooke) de Vries, 1969.

=*Eurotium stercorarium* Hansen, 1876.

=*Anixiopsis stercoraria* (Hansen) Hansen, 1897.

=*Anixiopsis fulvescens* var. *stercoraria* (Hansen) de Vries, 1969.

=*Aphanoascus cinnabarinus* Zukal, 1890.

non *Aphanoascus cinnabarinus sensu* Udagawa and Takada, 1973.

=*Anixiopsis reticulospora* Routien, 1967.

**Ascomata:** yellow-brown, becoming dark brown, 100-400*u*m diam. **Ascospores:** yellow-brown, ovoid, irregularly punctate and ridged, appearing spiny with LM, 4.0-5.5 x 5.0-8.5*u*m. **Asci:** globose to subglobose, thin-walled, 8-spored, 8.5-13*u*m. **Peridial hyphae:** flattened cells in layers, outer layer thick-walled. **Anamorph:** aleurioconidia solitary, long or short pedicellate or sessile; pyriform with a truncate base, hyaline, smooth to sparsely roughened, 7.0-8.0 x 10-12*u*m; sometimes forming globose "chlamydospores." **In culture:** [UAMH 4603]. CER 20/25°C creamy buff, felty to granular; reverse very pale orange. DSA 42/25°C creamy white, abundant, floccose mycelium with numerous reddish brown ascomata; reverse hyaline. PYE 21/25°C buff yellow, concentrically zonate with pale tan, densely felty; reverse yellow to pale brown.

**Material examined:** as *Anixiopsis* sp.: **TRTC** O-582/coyote dung/California; 32272/dog dung/Ontario; O-583/sheep dung/California; as *Anixiopsis stercoraria*: **UPS** Feurich/fox dung/Germany (natural material); **S** Feurich/cat dung/Germany (natural material); **TRTC** O-870/?/?; 36885/Ontario; 33516,

C317/bear dung/Ontario; 43978, 43979/carnivore dung/Ontario (natural material); 40388/carnivore dung/Massachusetts (natural material); 45246/carnivore dung/Nova Scotia (natural material); Cain, 19196/cow dung/Nebraska (natural material); 6604, 12398/dog dung/Ontario (natural material); 34044, 35716, 31641/dung/Ontario; 37242/fox dung/Ontario; Cain 697/fox dung/Quebec; Watling 47/kestrel pellet/England; **E** Watling 6024/sheep dung/Scotland; **TRTC** 32680, 38504/fox dung/Ontario; **S** Feurich/fox dung/Germany; **UPS** Nordin/fox dung/Sweden; **TRTC** 64-T-56-1 (*cultura desiccata*); 64-c-24-2/soil/Japan (*cultura desiccata*); 44886/weasle dung?/Ontario (natural material); as *Aphanoascus fulvescens*: **NY** CBS 111.58/bear dung/Canada; **TRTC** 43979/?/?; 6482/badger dung/Germany (natural material); 40142/cow dung/Idaho (natural material); 37710/fox dung/Argentina (natural material); Warcup A282/2/soil/Australia; 12397/bear dung/Ontario (natural material); 45329/carnivore dung/Ontario (natural material); 31323/fox dung/Ontario (natural material); 7686/dog dung/Ontario (natural material); **UAMH** 4603/dung/Alberta, coll. Currah.

**APINISIA** La Touche, 1968

Trans. Brit. mycol. Soc. **51**:283.

**Type species:** *Apinisia graminicola* La Touche.

**Ascomata:** white, globose, c. 200*u*m diam. When aggregate, globose to ovoid, up to 7000*u*m in diam. excl. appendages; **Ascospores:** yellow, globose with finely echinulate walls, 2.2-3.6*u*m diam. **Asci:** globose to subglobose, 5.7-7.6*u*m diam., 8-spored. **Appendages:** large pedicellate, septate, thick-walled, hyaline helical hypha 3.8*u*m wide, sometimes with tubercles; when tightly wound 26.6-34.4*u*m wide, up to 300*u*m long, emerging from the cleistoperidium. **Peridial hyphae:** hyaline, septate, thick-walled, branched, unequal, straight, curved or sinuate, smooth or rarely echinulate, forming an incompositothecium. **Ascocarp initials:** very short, irregular hyphae, some of which are branched once forming coils as they increase in size and forming tangled clumps. **Anamorph:** aleurioconidia - pyriform or clavate but occasionally irregular, lateral or terminal, 3.8-6.5 x 0.95-2.7*u*m and also intercalary conidia which are rectangular or irregular and about 1.9-3.8*u*m, in chains.

**Notes:** Cleistothecia bear a superficial resemblance to those of *Shanorella spirotricha* (Benjamin, 1956) in that the peridiam in both species are ultimately reduced to a mass of disunited, thick-walled cells.

*Apinisia graminicola* La Touche, 1968 Trans. Brit. mycol. Soc. **51**:283-285 FIG 1-19.

**Type material:** HOLOTYPE (*cultura desiccata*) **CMI** 126422 (rotting grass, England).

**Ascomata:** white, globose to ovoid, 200-700*u*m diam., excl. appendages. **Ascospores:** yellow, ochraceous in mass, globose, wall finely echinulate, 2.2-3.6*u*m diam. **Asci:** globose to subglobose, thin-walled, 5.7-7.6*u*m, 8-spored. **Peridial hyphae:** hyaline, septate, thick-walled, branched, unequal, straight curved or sinuate, smooth or echinulate, disarticulating, 2-15 x 10-40*u*m. **Appendages:** hyaline, pedicellate(?), septate, thick-walled, helical hyphae, 3.8*u*m in diameter, sometimes tuberculate, up to 300*u*m long. **Anamorph:** *Chrysosporium* state, aleurioconidia pyriform or clavate or irregular, lateral or terminal, 0.95-2.7 x 3.8-6.5*u*m, intercalary spores rectangular or irregular 1.9-3.8*u*m in chains. **In culture:** [UAMH 4315]. CER 50/25°C pale yellowish, thin, sulcate; reverse pale yellow, (numerous helices formed). DSA pale yellow white, dense, appressed to medium; reverse white. PYE 35/25°C cream, yellow to white, thick, densely felty, buckling; reverse concolorous.

**Notes:** La Touche indicates that this species is intolerant of high temperatures (will not grow at 27°C). Since the strain in UAMH has not fruited, I have taken the above description largely the original.

**ASCOCALVATIA** Malloch and Cain, 1971

Can. J. Bot. **49**:840.

**Type species:** *Ascocalvatia alveolata* Malloch and Cain

**Ascomata:** white, non-ostiolate, subglobose to globose, large ("small puffballs"). **Ascospores:** cylindrical to slightly allantoid, hyaline 4-5.5 x 2-3*u*m. **Asci:** subglobose to globose, 8-spored. **Appendages:** lacking. **Peridial hyphae:** thick, 2-layered. **Centrum characteristics:** sterile elements long, thickened on one

side ("elators"). **Anamorph:** arthroconidia. **Degrades:** keratin.

**Notes:** This genus has some similarities to *Onygena* in ascospore shape and the stromatic nature of the fruit bodies.

*Ascocalvatia alveolata* Malloch and Cain, 1970 Can. J. Bot. **49**:840.

**Type material:** HOLOTYPE (*cultura desiccata*) **TRTC** 45318 (carnivore dung, Ontario).

**Ascomata:** white, yellowish with age, 1-5mm diam., subglobose to globose, solitary. **Ascospores:** hyaline, cylindrical to slightly allantoid, smooth, 2.0-3.0 x 4.0-5.0*u*m. **Asci:** 6-8*u*m diam., separated by bands of sterile tissue, sterile hyphae 2.0-3.5*u*m wide. **Peridial hyphae:** pale yellow, membranous, 25-70*u*m thick. **Anamorph:** smooth, hyaline arthroconidia, 2.0-3.0 x 3.5-10.5*u*m, mostly non-septate, occasionally 1-3 septate.

**Notes:** Known only from the type.

**Material examined:** **TRTC** Holotype as cited.

AUXARTHRON Orr and Kuehn, 1963
Can. J. Bot. **41**:1439.

**Type species:** *Auxarthron californiense* Orr and Kuehn

=*Macronodus* Orr, 1977.

**Ascomata:** yellow-brown or orange-brown, to cinnamon to reddish brown, globose, <700*u*m diam.; reticuloperidium. **Ascospores:** hyaline or yellow or yellow-brown, spherical or oblate, minutely punctate to punctate-reticulate, appearing echinulate to reticulate, <5*u*m. **Asci:** hyaline, subglobose or globose or obovoid, evanescent, 7.2-8.0 x 10.6*u*m, 8-spored. **Peridial hyphae:** reddish or rusty or tan, enlarged at septa, thick, cuticularized, smooth to minutely to coarsely asperulate or tuberculate. **Appendages:** usually present, septate, asperulate, branches rare, tips round, subacute or acute; longer appendages septate with simple apices which are straight, bent, slightly coiled or uncinate. **Anamorph:** aleurioconidia and arthroconidia hyaline or light-colored, terminal, intercalary or rarely lateral, pyriform, oblong or cylindrical, variable in size. **Degrades:** keratin

**Notes**: This is a striking and beautiful group of ascomycetes with elaborate orange to reddish brown ascomata. Early isolates of taxa now assigned to *Auxarthron* were generally assigned to *Gymnoascus* or *Myxotrichum*, on the basis of the peridial structure and appendages. Both Apinis (1964) and Udagawa (1966) continued to consider species of *Auxarthron* in *Gymnoascus* even following Orr *et al.*'s, (1963a) pioneering monograph of the genus. Orr *et al.* first distinguished the species of *Auxarthron* from *Gymnoascus* on the basis of the presence of wall thickenings in the vicinity of septa which they called "knuckle joints." While these are common features of species of *Auxarthron*, knuckle joints also occur in *Gymnoascus reessii*, as well as in other taxa with reticulothecia. The main generic distinction to note is the presence of shallow puncta on the walls of the ascospores which are borne in very elaborate reticulothecia.

Indentify *Auxarthron* is usually quite easy although, as mentioned under *Amauroascus*, distinguishing these two genera can be difficult (see *Amauroascus kuehnii* and *Amauroascus pseudoreticulatus*. Species in *Auxarthron* are distinguished on the basis of shape and size of ascospsores. Particular attention must be paid to the pattern of puncta including size and number of pits. Shape of appendages and cells of the peridium are also important characters to consider. Slide cultures of anamorphs are useful if pure living cultures are available. Difficulties in using anamorphs as sources of taxonomic criteria arise when materials available are dried or are on natural substrata.

*Auxarthron* is a saprophyte found frequently on dung and in soil from the entrances of animal burrows. The genus is probably worldwide in distribution, but much more collection and isolation work is required.

*Auxarthron californiense* Orr and Kuehn, 1963 Can. J. Bot. **41**:1442-1443 FIG 1-2.

FIG 7.4, PL 7.4a,c, 7.5a,c, 7.10a

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** O-908 (pack rat dung, California).

=*Gymnoascus californiensis* (Orr and Kuehn) Apinis, Mycol. Pap. **96**:12, 1964.

**Ascomata**: rosy when young, orange to brown at maturity, 130-450*um* diam. excl. appendages. **Ascospores:** pale yellow-brown or hyaline, oblate, broadly punctate to appear reticulate (appearing echinulate at margin) 3.2-4.0 x 3.2-4.8*um*. **Asci**: ±globose, to 10.6*um* diam. **Peridial hyphae:** pale orange-brown, thick-walled, asperulate, cuticularized, anastomosed, septate, knuckle-joints to 6.4-9.6*um* wide, apices short, spine-like, asperulate, rounded or blunt 9.6-26*um*. **Appendages**: orange-brown, smooth, straight to curved/bent, occasionally branched with basal knuckle-joints, apices uncinate, 72-375*um* in length (about the diam. of the ascoma ). **Anamorph:** conidia pale orange, terminal, intercalary, smooth to minutely rugose, 2.0-2.5 x 3.5-6.0*um*. **In culture:** [UAMH 1889]. CER 28/25°C camel-colored with faint pale orange cast, thick and velvety; reverse rosy tan. DSA 42/25°C abundant rust-brown ascomata on sparse, hyaline vegetative mycelium; reverse uncolored. PYE 28/25°C velvety, heaped, luxurious, cream to pale yellowish; reverse yellow-tan.

**Notes:** This very distinct species is superficially similar to *Uncinocarpus uncinatus*, but is easily distinguished on size and appearance of ascospores. The two share thick-walled, uncinate appendages, but the crozier-shaped tips of *Auxarthron californiense* taper to an acute end while the tips of the other remain parallel and have blunt termini. Apinis (1964) examined collections of this taxon on the fungus *Scleroderma vulgare*, cellophane which had been buried in a calcareous fen, and bird dung.

**Material examined: RSA** 1525 (=NRRL A-11,022, =UAMH 1591, 1889, 3151, =NY O-908) (type strain as cited); 1241 (=UAMH B-3111)/dung/California; 1262/dung/Oregon; **E** Watling 4050/rabbit dung/Scotland; as *Gymnoascus californiensis*: **BP** 54228/deer dung/Hungary.

*Auxarthron compactum* Orr and Plunkett, 1963 Can. J. Bot. **41**:1453-1454 FIG 24-25.

FIG 7.5, PL 7.6a, 7.9d

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** O-573. (rat dung, California).

**Ascomata:** brown, spherical, 310-675*um* diam., excl. appendages.

**Ascospores:** hyaline to pale tan, oblate, 2.4-3.6*um*, reticulate-echinulate. **Asci:**

±globose, 6.5-9.0*um* diam. **Peridial hyphae:** pale orange brown, finely to roughly asperulate, thick-walled, apices few, blunt, short, spine-like, septate, individual cells short and broad, knuckle joints 3.6-5.4*um* diam. **Appendages:** orange-brown, fading to tip, one basal knuckle-joint, 350-600*um*, slightly bent to coiled apically. **Anamorph:** arthro and aleurioconidia, hyaline to pale yellow and variable in size. **In culture:** [UAMH 3153]. CER 35/25°C sparse, wave-like, pale creamy ochre with mounds of discrete ascomata; reverse orange-brown. DSA 42/25°C sparse, pale yellowish white with numerous brown ascomata; reverse pale yellow. PYE 56/25°C wrinkled, rugose, ochre-brown; reverse red-brown.

**Notes:** This species is distinguished from others in the genus on the basis of the short, squat, thick-walled cells of the peridial hyphae.

**Material examined: NY, RSA, UAMH** (type as cited); **UAMH** 3152 (=O-36)/kangaroo rat lung/California; 3153 (=RSA 1527) /rat dung/California; as *Gymnoascus zuffianus*: **UPS** Gunnerbeck/roe dung/Sweden.

*Auxarthron conjugatum* (Kuehn) Orr and Kuehn, 1963 Can. J. Bot. **41**:1452-1453

FIG 22-23.

<u>FIG 7.6, PL 7.6c,d, 7.7a,c, 7.9e, 7.10b</u>

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** O-520 (soil, Arizona).

≡*Myxotrichum conjugatum* Kuehn, Mycologia **47**:883, 1955 (Basionym).

=*Macronodus bifurcatus* Orr, Mycotaxon **5**:284, 1977.

≡*Gymnoascus bifurcatus* (Orr) Von Arx, 1981 (page 132).

**Anamorph name:** *Malbranchea* state of *Auxarthron conjugatum*, *fide* Sigler and Carmichael, 1976.

**Ascomata:** pale orange or yellow-brown, spherical, 235-540*um*, excl. appendages. **Ascospores:** hyaline to pale tan or yellow-orange, oblate, finely punctate-reticulate, 1.8-2.5 x 2.5-3.8*um*. **Asci:** hyaline, ellipsoidal, obovoid, 4.2-5.0 x 6.8-8.2*um*. **Peridial hyphae:** pale yellow or orange-brown, smooth to asperulate, thick-walled, 2.6-3.0*um* wide, septate knuckle-joints 3.2-6.0*um* wide, apices spine-like, asperulate, rounded to acute, 9-96*um* in length. **Appendages:** orange to red-brown, fading to apex, occasionally with small, terminal dichotomies or branches, non-septate straight, bent, hooked, coiled, 2.8-3.2 x

226-1550$um$. **Anamorph**: hyaline to pale yellow, terminal or intercalary, on lateral, curving branches 1.2-1.5 x 2.5-5.0$um$ or 3.0 x 3.0-5.0 when borne on main hypha (these becoming subglobose with age). **In culture**: [UAMH 3156]. CER 35/25°C ochre in central region, surrounded by yellow-ochre, powdery texture; DSA 112/25°C numerous brown ascomata with a few patches of thick, creamy white mycelium; reverse uncolored. PYE 28/25°C cottony growth over coffee-brown mat; reverse wine red.

**Notes:** A detailed discussion of the anamorph is presented in Sigler and Carmichael (1976). *Macronodus bifurcatus* was described by Orr (1977) as a somewhat similar fungus which differed on the basis of the branching pattern of the appendages and sculpturing on the ascospores. The types of the two taxa appear identical to me. Ascospores are identical by SEM. Von Arx (1981) recognized the taxon as *Gymnoascus bifurcatus*.

*Auxarthron conjugatum* is similar to *Auxarthron umbrinum* which in not having bifurcate appendages, and having minutely punctate ascospores which are more broadly oblate.

**Material examined: NY** O-532/?/?; O-789/kangaroo rat lung/California; O-948/lizard dung/California. **RSA** 1474, 1475 (=UAMH 3130)/lizard dung/Mexico; as *Gymnoascus* sp.: **TRTC** Cooke, 1999/creek sediment/Ohio **UAMH** 3156 (type as cited), from RSA as RSA 1530; 3519/soil/Sudan; 3817 (=O-1236)/soil on horn/India; 3841 (=O-3153) feathers/Queensland; 3874 (=O-3750)/soil/Kansas (type of *Macronodus bifurcatus*); S161 (Emmons A-4718)/rodent lung/Texas.

*Auxarthron pseudauxarthron* Orr and Kuehn, 1972 Mycologia **64**:67 FIG 13-15.

**Type material**: HOLOTYPE (*cultura desiccata*) **NY** O-3083 (rabbit dung, Utah).

**Ascomata:** yellow or yellow-brown, spherical, 220-650$um$ diam. (incl. appendages). **Ascospores:** hyaline to pale yellow, spherical, 2.3-3.2$um$ diam., finely punctate-reticulate. **Asci:** ±globose, to 11.4$um$ diam. **Peridial hyphae:** forming a lax, open network, yellow-brown or brown, septate, walls thick, finely asperulate, cells elongate. **Appendages:** yellow-brown, lacking knuckle-joints, 40-110$um$ long, smooth/finely asperulate with rounded apices.

**Anamorph:** not observed. **In culture:** [UAMH 3404]. CER 40/25°C greenish in central area, perimeter white; reverse pale green. DSA 49/25°C yellowish tan; reverse pale yellow. PYE 40/25°C white, cottony, concentrically zonate with greenish tinge in central area; reverse brown (to almost black) in centre grading to tan at perimeter.

**Notes:** Easily identified on the basis of ascospore morphology and the long cells of the lax, open reticuloperidium. This is the only *Auxarthron* species for which an anamorph has not been recorded.

**Material examined:** **UAMH** 3404 (type strain as cited).

*Auxarthron reticulatum* (Zukal) Orr and Plunkett, 1963 Can. J. Bot. **41**:1443-1445.

**Type material:** NEOTYPE (*cultura desiccata*) **NRRL** A10748. (wood slat from greenhouse flat, California).

≡*Gymnoascus reticulatus* Zukal, Verh. Zool. Bot. Ges. Wien **37**:40, 1887 (Basionym).

**Ascomata:** rosaceous when young, becoming dark brown or brownish with yellow, orange, or red overtones, 90-400*u*m diam. incl. appendages. **Ascospores:** hyaline to pale yellow, globose, 2.2-3.6*u*m diam., reticulate-echinulate. **Asci:** ±globose, 8.2-12.2*u*m diam. **Peridial hyphae:** yellow-brown, thick-walled, asperulate, septate, knuckle-joints 3.2-5.6*u*m wide free apices truncate. **Appendages:** short, spine-like, asperulate, blunt, rounded, slightly subacute, 6-35*u*m. **Anamorph:** hyaline to pale yellow, terminal and intercalary, 2.0-3.0 x 2.5-6.0*u*m. **In culture:** [UAMH 1585]. CER 21/25°C even textured white mat, ascomata abundant in central area; reverse yellow. PYE 21/25°C yellowish cream, abundant heaped zonate to sulcate growth; reverse orange chestnut.

**Notes:** Orr stated there were some doubts regarding the accurate usage of Zukal's name, since Zukal described the ascospores as being larger (6.4*u*m), and ellipsoid to lenticular. The presence of swollen septal regions in the hyphae of the peridium supported the transfer of the species to *Auxarthron*. Some collections received during this study, as *Arachniotus reticulatus* and *Auxarthron*

*reticulatum*, actually represented species of *Amauroascus* based on the deep puncta of the ascospores. I have been able to place these in either *Amauroascus kuehnii* or *Amauroascus pseudoreticulatus*.

**Material examined: RSA** 1528 (=UAMH 1585, 1659, 3154) neotype strain as cited; 1438, 1439, 1490/lizard dung/Mexico.

*Auxarthron umbrinum* (Boudier) Orr and Plunkett, 1963 Can. J. Bot. **41**:1446-1449 FIG 9, 13-19.

PL 7.10d

**Type material**: HOLOTYPE strain(?) **CBS** O-1030 (obtained from the Pasteur Institute, Paris and thought to be Boudier's original strain, no collection data available but probably from France).

≡*Gymnoascus umbrinus* Boudier, Bull. Soc. Mycol. Fr. **8**:43, 1892.

=*Myxotrichum brunneum* Rostrup, Bot. Tidssk. **19**:206, 1895.

≡*Auxarthron brunneum* (Rostrup) Orr and Kuehn, Can. J. Bot. **41**:1446, 1963.

=*Gymnoascus subumbrinus* Smith, Trans. Brit. mycol. Soc. **5**:424, 1917.

=*Myxotrichum emmonsii* Kuehn, Mycologia **47**:539, 1955.

?=*Myxotrichum thaxteri* Kuehn, Mycologia **47**:878, 1955.

≡*Auxarthron thaxteri* (Kuehn) Orr and Kuehn, Mycologia **63**:200, 1971.

**Ascomata:** light to dark brown or red-brown, spherical, 180-600*um* excl. appendages. **Ascospores:** yellow to pale brown, finely punctate-reticulate, oblate, 1.8-3.2 x 2.0-4.2*um*. **Asci:** ±globose, to 10*um* maximum. **Peridial hyphae:** yellow-brown to brown, smooth to asperulate, septate, knuckle joints to 9.6(-16)*um* diam., anastomosed, free apices spine-like, asperulate with rounded apices, 3.8-56*um*, adjacent spines may anastomose at base. **Appendages:** brown, paler toward apex, numerous, 2.7-3.3*um* wide, non-septate except at basal knuckle-joints, apices uncinate, straight bent, sinuate or coiled, 250-1350*um* long. **Anamorph:** hyaline, terminal conidia pyriform; intercalary conidia variable, 1.2-3.6 x 2.8-9.6*um*. **In culture:** [UAMH 3952]. CER 28/25°C concentrically zonate, some sectoring, fuzzy felty ochre-yellow, ascoma production in centre is heavy; reverse rich wine-red brown at centre fading to

pale orange-yellow at margin. DSA 42/25°C white, densely felty; reverse uncolored. PYE 35/25°C rust-orange in centre paling to cream-yellowish white at margin, luxuriant cottony growth; reverse orange to reddish yellow.

**Notes:** Easily confused with *Auxarthron conjugatum*. A detailed comparative study of the two species is required. At present, they are distinguished on the basis of size and ornamentation of the ascospores: *Auxarthron conjugatum* has slightly larger and more coarsely punctate ascospores than *A. umbrinum*. Appendages of *A. conjugatum* are frequently branched or bifurcate, while those of *A. umbrinum* are simple.

**Material examined: FH** Thaxter 599/*Isaria farinosa*/Massachusetts. **NY** B30/soil/England; O-236, -310/soil/California; O-561/lizard dung/California; O-832/?/CDC Georgia; O-901/pine forest soil/England; O-1023/soil/England; O-1027/pack rat lung/Texas; O-3168/lab contaminant/Utah. **RSA** 54/dung/Illinois; 82/dead beetle/California; 413/lizard dung/Haiti (type of *Myxotrichum thaxteri*; 418/*Neotoma*/Texas; 1484/lizard dung/Mexico. **TRTC** CMI 41112/soil/England. **UAMH** 3952 from Orr as type strain; 4484/prairie dog dung/Alberta; 4784/dung/Alberta; 4814/coyote dung/Alberta.

*Auxarthron zuffianum* (Morini) Orr and Kuehn, 1963 Can. J. Bot. **41**: 1445-1446.

FIG 7.8, PL 7.6f, 7.10c

**Type material:** NEOTYPE (*cultura desiccata*) **NY** O-514 (prairie dog lung, Texas).

=*Gymnoascus zuffianus* Morini, Mem. R. Accad. Sci. Bologna **IV 10**:205, 1889 (Basionym).

=*Gymnoascus eidami* Cocconi, Mem. R. Accad. Sci Bologna V 2:32, 1891 *fide* Orr *et al.*, 1963a.

=*Gymnoascus brevisetosus* Kuehn, Mycologia **48**:813, 1956 *fide* Orr *et al.* 1963a.

**Ascomata:** orange-brown to brown, 195-600 diam. incl. appendages. **Ascospores:** hyaline to yellow or yellow-brown, globose to subglobose, 2.4-3.6*u*m, punctate-reticulate. **Asci:** hyaline, obovoid, 5.6-7.0 x 7.0-8.4*u*m,

8-spored. **Peridial hyphae**: pale orange-brown, smooth to asperulate, thick-walled, cuticularized, dichotomously anastomosed, knuckle-joints 2.4-5.8*um* wide, free apices form appendages. **Appendages:** pale orange-brown, short, spine-like, smooth to asperulate, straight or curved, occasionally bifurcate from the base, apices pointed 10-85*um* long. **Anamorph**: terminal, pyriform aleurioconidia or intercalary, cylindrical or oblong arthroconidia, 2.0-5.0 x 3.0-8.0*um*, sometimes becoming swollen and ±globose. **In culture:** [UAMH 1875]. CER 14/25°C snow-white, yellowish in centre, flat felty to granular; reverse yellow. DSA 42/25°C yellowish white, reverse pale yellow. PYE 21/25°C white, thick and dense; reverse orange in centre, yellow at perimeter.

**Notes:** The long, acutely pointed spines, distinguish this species from *Auxarthron reticulatum* which has shorter, blunt spines. *A. zuffianum* is primarily coprophilous. I have found a similar species on coyote dung (PL 7.8c,d).

**Material examined: NY** 0-514/ (=UAMH, 1875)/prairie dog lung/Texas; (type of *Gymnoascus brevisetosus*). 0-608/kangaroo rat lung/California; 0-3663/soil/Australia; DPG 99/sand/Utah. **RSA** 517/rabbit dung/California; 806/soil/Mexico; 1479 (=UAMH 3135),1487 (=UAMH 3142), 1504 (=UAMH 3150)/lizard dung/Mexico. **TRTC, UPS** Nordenstan/babboon dung/S. W. Africa. **UAMH** 3079 (=CMI 76603) soil/England; 4082 (=CDC Y-333), 4098 (=CDC Y-337), 4566/soil/Argentina.

**KERATINOPHYTON** Randhawa and Sandhu, 1964
Sabouraudia **3**:252.

**Type species:** *Keratinophyton terreum* Randhawa and Sandhu

**Ascomata:** light- to dark- brown, subglobose to globose, glabrous, non-ostiolate. 270-670*um* diam. **Ascospores**: light yellowish brown, smooth on the faces with a low irregular equatorial crest. 1.7-3.3 x 3.3-5.0*um*. **Asci:** ovoid to globose, 4.2-6.7 x 6.7-8.4*um*, 8-spored. **Appendages**: lacking. **Peridial hyphae:** flattened, reddish brown, polygonal cells forming a membrane. **Anamorph:** *Chrysosporium*-like; aleurioconidia borne at the ends of undifferentiated hyphae. **Degrades:** keratin

**Notes**: Apinis (1968) placed the type species in *Aphanoascus*, but in fact these taxa are quite distinct. The ascospores of the two species included here in *Keratinophyton* each have a punctate equatorial band with smooth, broad, flattened polar areas. *Aphanoascus* species have irregular reticulations over the entire ascospore. They are similar with respect to the construction of the peridium and the nature of the anamorph.

*Keratinophyton durum* (Zukal), comb. nov. .

FIG 7.9, 7.15d

**Type material:** PROPOSED NEOTYPE (*cultura desiccata*) **UAMH** 856 (chicken yard soil, Alberta).

=*Gymnoascus durus* Zukal, Ber. dtsch. bot. Ges. **8**:8 295, 1890 Taf XVII FIG 1-4, 9.

**Ascomata:** light grayish brown, globose, subglobose, 100-1500*u*m diam. **Ascospores:** yellowish brown, thick-walled, oblate with wide, slightly roughened, equatorial crest, (1.7-)2.5 x 3.0-4.5*u*m; with SEM, crest is minutely and regularly punctate, lateral faces smooth. **Asci:** 6.2-7.5*u*m diam., 8-spored. **Peridial hyphae:** yellowish brown, smooth, thick-walled cells, multilayered forming a membranous wall. **Anamorph:** hyaline, smooth-walled, solitary, clavate, sessile aleurioconidia, 0-1-septate, 2.0-3.0 x 4.0-11*u*m. **In culture:** [UAMH 856 =type strain] CER 21/25°C white, somewhat radiately fibrillose, thin; reverse pale yellow; DSA 42/25°C white, scant mycelium, scattered; reverse uncolored. PYE 28/25°C cream to tan, dense, thick, felty; reverse pale brown.

**Notes:** It is interesting that Zukal's original description contains an extremely accurate rendition of ascospore shape (Taf XVII FIG 9), which agrees in all respects with SEM results obtained here.

**Material examined: UAMH** 856/chickenyard soil/Alberta, coll. Carmichael; 3671/hedgehog/Ivory Coast.

*Keratinophyton terreum* Randhawa and Sandhu, 1964 Sabouraudia **3**:253 FIG 1-7.

FIG 7.10

**Type material:** HOLOTYPE **V.P. Chest Institute, University of Delhi** Kr951/3 (fowl pen soil, India).

=*Aphanoascus terreus* (Randhawa and Sandhu) Apinis, Mycopathol. et Mycol. Appl. **35**:99, 1968.

**Ascomata:** pale tan to dark brown, globose, subglobose or ovoid, 280-670*u*m. **Ascospores:** light yellowish brown, smooth, thick-walled, oblate with irregular equatorial rim, 1.7-3.3 x 3.3-5.0*u*m. **Asci:** globose to ovoid, 4.2-6.7 x 6.7-8.4*u*m, 8-spored. **Peridial hyphae:** brownish yellow, smooth, thin-walled cells, 2.7-7.4 x 5.5-12.0*u*m composing a multilayered, membranous wall, 18-55*u*m thick. **Anamorph:** aleurioconidia unicellular, hyaline, clavate, slightly roughened, solitary on vegetative hyphae, 1.7-4.2 x 3.3-12*u*m. Arthroconidia and chlamydospores also formed but not frequent. No macroconidia were observed in any of the material examined. **In culture:** [UAMH 2409] CER 14/25°C white, granular, flat; reverse slightly yellow. DSA 42/25°C scant white mycelium around hair, scattered knots of white hyphae with a few brown ascomata in vicinity of hair; reverse uncolored. PYE 14/25°C pale cream, felty; reverse pale yellowish brown.

**Notes:** This species is distinguished from *Keratinophyton durus* by having an asymmetrical equatorial band. The anamorph of this species was named *Chrysosporium indicum* (Randhawa and Sandhu) Garg (1966).

**Material examined: UAMH** 2409/hair-baited soil/Kenya; 2561/domestic fowl/Australia; 2748/soil/Mozambique; 4616/soil/Spain.

## KUEHNIELLA Orr, 1976

Mycotaxon **4**:171.

**Type species:** *Kuehniella racovitzae* (Lagarde) Orr.

**Ascomata:** white, globose. **Ascospores:** hyaline, globose, walls irregularly ridged and punctate. **Asci:** spherical, 8-spored. **Appendages:** helical hyphae. **Peridial hyphae:** similar to vegetative hyphae. **Anamorph:** arthro and aleurioconidia.

**Notes:** Von Arx (1977) placed the genus in synonymy with *Arachnotheca* [*Kuehniella racovitzae* (Lagarde) Orr =*Arachniotus albicans* =*Arachnotheca albicans* (Apinis) Von Arx (1977)] but this is inappropriate since ascospores of the types are very different. Not only does *Arachnotheca* have sheathed spores, it also

has fission arthroconidia. "*Arachniotus albicans*" which is a species of *Amauroascus* q.v., is distinctly different again.

*Kuehniella racovitzae* (Lagarde) Orr, 1976 Mycotaxon **4**:171-178.

PL 7.16

**Type material:** NEOTYPE (*cultura desiccata*). **NY** O-3436 (dog lesion, Kansas) *fide* Orr, 1976.

=*Myxotrichum racovitzae* Lagarde, Arch. Zool. Exper. Gener. **53**:280, 1913.

=*Gymnoascus racovitzae* (Lagarde) Lagarde, Arch. Zool. Exper. Gener. **53**:281, 1913.

**Ascomata:** white, ±spherical, 50-1400*u*m diam. excluding appendages, confluent. **Ascospores:** hyaline, globose, 2.3-4.2*u*m diam., thick-walled, finely and irregularly punctate-reticulate. **Asci:** spherical, 5.7-11.4*u*m diam., 8-spored. **Peridial hyphae:** loose arrangement of apparently undifferentiated vegetative hyphae, forming a telaperidium **Appendages:** helical appendages forming at periphery of ascoma , variable in length and number of turns. **Anamorph:** hyaline, aleurioconidia pyriform, 2.2-4.2 x 5.6-6.7*u*m; arthroaleurioconidia ±cylindrical, 1.9-2.9 x 4.2-9.5*u*m. **In culture:** [UAMH 3767]. CER 42/25°C white, felt-like, uniform; reverse brown. DSA 42/25°C white to pale brownish yellow, sectored mycelium, sparse but extensive; reverse concolorous with rosy brown areas. PYE 14/25°C cream, buff or pale tan, slightly cottony with numerous white knots, submerged in vegetative hyphae; reverse yellowish brown.

**Notes:** Holotype was obtained from rotting wood found in a cave in France. Other isolations are recorded from "organic matter", insect remains, dog lesion, sputum, mouse dung and soil. I found this species once on carnivore dung which had been collected in southern Alberta.

**Material examined: FH, NY** (type as cited); O-3212/sputum/Kansas; O-1294/mouse dung/Colorado; *UAMH* 3767 (type strain as cited), from Orr.

## NANNIZZIOPSIS gen. nov.

*Typus: Nannizziopsis vriesii (Apinis) comb. nov.*

*Ascoma alba dein griseo-lutea, globosa, <1mm diam. Ascosporae hyalinae,*

*minutae, globosae cum foveis multiangulis, <3.5um. Asci globosi vel subglobosi, octospori, <8um diam. Hyphae peridii hyalinae, asperulatae, septae constrictae, ramosae et anastomosae. Appendicula hyalina, simplex, aut quod discerni non potest. Stat. conid. aleuriosporae et arthrosporae.*

**Ascomata:** white, becoming grayish yellow, globose, <1mm diam. **Ascospores:** hyaline, small, globose with polygonal pits. **Asci:** globose to subglobose, 8-spored, <8*u*m diam. **Peridial hyphae:** hyaline, constricted at septa, branched and anastomosed, asperulate. **Appendages:** hyaline, simple or indistinguishable from peridial hyphae. **Anamorph:** aleurioconidia and arthroconidia.

**Notes:** Apinis' concept of the genus *Rollandina* accommodated *Rollandina vriesii* primarily on the basis of the nature of the hyphae found on the stalk of Patouillard's collection named *Rollandina capitata.* This collection consists of at least two separate fungi and I have followed Von Arx (1971) in rejecting the genus name on the grounds that it is a *nomen confusum.* The keratinolytic capacity and punctate ascospore walls place *Rollandina vriesii* in the Onygenaceae. Since it does not closely resemble any of the other genera in that family, it is described here as a new genus.

The asperulate peridial hyphae with septal constrictions closely resemble the peridial hyphae found in *Arachnotheca*. *Arachnotheca* however has sheathed ascospores and a distinctive anamorph of fission arthroconidia.

Peridial hyphae, typical of *Nannizziopsis,* occur also in collections labelled *Onygena bommerae* (BR) and *"Ctenomyces"* (FI). Both collections lack ascospores corresponding to *Rollandina vriesii* although the material at FI has typical *Gymnascella aurantiaca* ascospores in some parts of the material.

Because of the presence of similar peridial hyphae and puncta on the ascospores, I suggest that *Apinisia queenslandica* should probably be transferred to *Nannizziopsis*. It appears to be more closely related to *Nannizziopsis vriesii* than to *Apinisia graminicola* which, from the original description, most closely resembles *Shanorella*. Apinis and Rees (Trans. Brit. mycol. Soc. **67**:524, 1976 FIG 1A-J) described *Apinisia queenslandica* (based

on HOLOTYPE CMI 121675, from feathers, Australia) as follows: **Ascocarps:** brown at maturity, globose, soft(?), solitary or gregarious, 350-1000(-1540)*u*m diam. **Ascospores:** globose, ellipsoidal (lens-shaped), yellow becoming brown, thick, finely verrucose wall, 3.5-5(5.3)*u*m diam. **Asci:** globose to ovoid, 7-12.0 x 9.5-13(15)*u*m, 8-spored. **Peridial hyphae:** hyaline, finely verrucose, anastomosed, septate, 4-6*u*m thick, somewhat constricted at septa. **Appendages:** brown, smooth, septate, irregularly helical, 1.5-4.0*u*m. **Anamorph:** *Chrysosporium queenslandicum* Apinis and Rees; aleurioconidia hyaline, aseptate, single or in short chains, smooth, pyriform, 2.5-3.5(4.1)*u*m. The type strain (UAMH 4319) has not ascosporulated and formal disposition of the species requires information not provided by the original description or by the strain available.

*Arachniotus hebridensis* according to Apinis (1964) also appears to be closely related to *Nannizziopsis*. I have not examined the holotype but the type strain received by UAMH is a strain of *Geomyces pannorus* (Hyphomycetes). It is possible that this was a contaminant in the original isolate. Udagawa and Takada (1968 and 1973) applied the name *Arachniotus hebridensis* to isolates from pig dung and soil, Japan. This taxon is keratinolytic but has not fruited at UAMH. Further work with these collections is needed before they can be named.

*Nannizziopsis vriesii* (Apinis) comb. nov. .

FIG 7.11, PL 7.11a,b

**Type material:** HOLOTYPE (*cultura desiccata*) **CMI** 149994 ("Amieva" skin, Holland?).

=*Rollandina vriesii* Apinis, Trans. Brit. mycol. Soc. **55:** 499-502, 1970 FIG 1A-Z (Basionym).

=*Arachnotheca vriesii* (Apinis) Samson *apud* Von Arx, 1981a

**Ascomata:** white, becoming grey to yellowish, globose, solitary or gregarious, 300-1000*u*m diam. **Ascospores:** hyaline, appearing spiny to reticulate with light microscope, globose, 2.0-3.0*u*m diam. **Asci:** ±globose, 6.0-8.0*u*m diam., 8-spored. **Peridial hyphae:** hyaline, branched and anastomosed, constricted at septa, asperulate, 2.5-5.0*u*m diam. **Appendages:** a few long, smooth, hyaline hyphae. **Anamorph:** hyaline, smooth arthroconidia, and pyriform to clavate

aleurioconidia, 2.0-3.0 x 3.0-8.0$u$m. **In culture:** [UAMH 3527]. CER 21/25°C white, heaped in localized patches; reverse very pale yellowish cream. DSA 42/25°C white, scant, reverse white. PYE 21/25°C white, dense, cracking (or with small fissures) when dried; reverse white except at margin where yellow-orange band is formed.

**Notes:** Known only from type collection and one collection at FH.

**Material examined: UAMH** 3527 from CBS, ( =UAMH 3598 from CMI) (type strain as cited); **FH** "roach wing," Trinidad.

## NEOGYMNOMYCES Orr, 1970

Can. J. Bot. **48:**1061.

**Type species:** *Neogymnomyces demonbreunii* (Ajello and Cheng) Orr

**Ascomata:** yellowish, ±spherical. **Ascospores:** pale yellow, irregularly grooved, ovoid, <4.5$u$m maximum. **Asci:** hyaline, globose or obovoid, 8-spored. **Peridial hyphae:** hyaline, smooth, thick-walled, sinuous, free ends form simple or branched appendages. **Appendages:** hyaline, simple, or unequally bifurcate, sinuous, smooth, septate, apices rounded or swollen. **Thallism:** homothallic. **Anamorph:** aleurioconidia and arthroconidia. **Degrades:** keratin.

**Notes:** Von Arx (1974) placed this genus in synonymy with *Gymnoascus* even though Orr's account of *Neogymnomyces* was carefully defended (1970).The light microscope reveals that the ascospores are definitely sculptured but this feature has never been documented. Sculptured ascospores, the rhexolytically dehiscing conidia, and the ability to degrade keratin, adequately distinguish *Neogymnomyces* from *Gymnoascus*, and confirm its placement in the Onygenaceae.

*Neogymnomyces demonbreunii* (Ajello and Cheng) Orr, 1970 Can. J. Bot. **48:**1061 FIG 1-8.

<u>PL 7.4b, 7.11,c,d</u>

**Type material:** NEOTYPE (*cultura desiccata*) **NY** ATCC 18394 (soil, Missouri).

=*Gymnoascus demonbreunii* Ajello and Cheng, Mycologia **59:**692, 1967 (Basionym).

**Ascomata:** yellowish or golden, discrete, ±spherical, 73-400$u$m diam., naked

asci also present in culture. **Ascospores:** yellowish, spherical, discoid-oblate, punctate to almost smooth, 2.5-3.0 x 2.5-4.4*u*m. **Asci:** hyaline, globose or obovoid, 5.3-6.5 x 8.6-8.8*u*m. **Peridial hyphae:** hyaline, smooth, thick-walled, septate, sinuous, anastomosed. **Appendages:** hyaline, 25-260*u*m long, apices simple, blunt or with short dichotomous branches. **Anamorph:** arthroconidia and aleurioconidia, variable in size and shape, o 14.2*u*m long. **In culture:** [UAMH 3382]. CER 35/25°C yellow tan, granular with concentric white zones, radiately sulcate; reverse brownish yellow. DSA 42/25°C white, granular, pale brown; reverse yellow. PYE 28/25°C faintly concentrically zonate (pale yellow with pale tan); reverse yellow to pale orange-brown.

**Notes:** Orr's ascospore measurements are rather small. Ajello and Cheng (1967) originally described *Gymnoascus demonbreunii* as the sexual state of *Histoplasma capsulatum* Darling. This was refuted by Kwon-Chung (1968) and Orr (1970). The species is known from two isolations: human, Puerto Rico; and soil, Missouri.

**Material examined:** **UAMH** 3382 (type strain as cited).

**NEOXENOPHILA** Apinis and Clark, 1974

Trans. Brit. mycol. Soc. **63**:263.

**Type species:** *Neoxenophila foetida* Apinis and Clark.

**Ascomata:** globose to subglobose, tomentose, non-ostiolate, ±aggregated superficial. **Ascospores:** globose to ovoid (oblate?), <5.0*u*m maximum. **Asci:** globose to ovoid. **Appendages:** lacking. **Peridial hyphae:** form 3 distinct layers: 1. an outer layer of loose vesicular hyphae with hyaline appendages; 2. a brown membranous layer of flattened cells; and, 3. an inner layer of hyaline pseudoparenchymatic cells. **Anamorph:** *Chrysosporium* anamorph, conidia 0-1 septate.

**Notes:** As the name implies, there is a striking resemblance between this genus and *Xynophila* q.v. Examination of the holotype may prove that there are no grounds for maintaining this genus as a distinct taxon.

*Neoxenophila foetida* Apinis and Clark, 1974 Trans. Brit. mycol. Soc. **63**:263-264.

**Type material:** HOLOTYPE (*cultura desiccata*) **CMI** 156967 (rat, Nigeria).

**Anamorph name:** *Chrysosporium foetida* Apinis and Clark.

**Ascomata:** brownish, 200-400*um* diam., hairy, globose to subglobose, ±aggregated, superficial. **Ascospores:** hyaline to brown, globose to ovoid, 1.5-2.7 x 3.5-4.8*um*, apparently smooth. **Asci:** subglobose to ovoid, evanescent, 5.5-6.5 x 7.0-10.0-15*um*. **Peridial hyphae:** 3-layered: outer layer of loose vesicular hyphae; middle layer of brown membranous cells; inner layer of hyaline membranous hyphae. **Anamorph:** Microconidia hyaline, smooth, 1-celled, 2-3.5 x 3-8(10)*um*. Macroconidia hyaline, smooth, clavate, 2.5-5 x 10-25(-30)*um* "similar to *Trichophyton*." Chlamydospores hyaline apical or intercalary, globose to ovoid or clavate **In culture:** no data.

**Notes:** Tentative placement until holotype examined.

**Material examined:** none; description from original.

## ONYGENA Persoon 1795

Observationes Mycologicae **2**:71.

**Type species:** *Onygena equina* (Wildenow) Persoon.

**Ascomata:** borne in a white to brown, chinky or rugulose, globose ascostroma borne on the apex of a cylindrical or somewhat flattened stipe, 500-1000*um* diam. and up to 1.5cm long. **Ascospores:** hyaline to tan, ellipsoidal to slightly reniform or allantoid, broadly rounded at both ends, smooth to minutely asperulate. **Asci:** arising from croziers among tissue of stroma of the capitulum, to 14*um*. **Appendages:** lacking. **Peridial hyphae:** stroma composed of hyaline, polygonal and filamentous cells. **Thallism:** unknown. **Anamorph:** *Sporendonema* state.

**Notes:** Gaumann (1928) briefly mentioned the formation of multiple ascogenous coils within the capitulum of *Onygena*. This has been observed also by Malloch (1981). For this reason, and after examining squashes of numerous dried specimens, I feel that the head of *Onygena* (long regarded as an individual ascocarp) represents a stroma which encloses a number of individual ascomata.

Unfortunately there are no published developmental studies to confirm this.

There are two species in the genus: *Onygena corvina* and *Onygena equina*. A third recognizable taxon which has been placed in the genus is *Onygena caprina* Fuckel (see PL 7.13d, 7.14a,b,c). (**Ascomata:** buff to tan brown, clustered, spherical or irregular, 1.2-3.5mm diam. **Ascospores:** reddish brown, limoniform, 4.5-5.5 x 6.0-9.0*u*m. **Asci:** spherical, 13-15*u*m, oblate with scalloped equatorial frill in polar view, 3.9-4.7 x 8.0-8.6*u*m. **Peridial hyphae:** tightly woven hyphae. **Appendages:** lacking. **Anamorph:** unknown. **In culture:** none known). I have examined four collections of this species ( **TRTC** Demetrio 2687/cow horn/Missouri; **NY** Demetrio 268/cow horn/Missouri; **PAV** 246/horn/?; **G** Barb. Bois./horn/?), and feel that it requires reallocation. The ascospores are not punctate, but resemble large *Gymnascella marginospora* ascospores. It has only been found on keratinous materials in nature. There is no information on the anamorph and the organism does not exist in culture. Reallocation should await the availability of fresh isolations.

The unique macroscopic nature of *Onygena corvina* and *O. equina* has invited attention from many mycologists. They are usually considered macrofungi, and consequently receive attention from those who compile regional floras (see Breitenbach and Kranzlin, 1981 ?plates 374 and 375?).

I have observed either type or authentic material for the following species, formerly disposed in *Onygena*. Some suggestions as to the identity of these taxa are provided.

*Onygena alpina* (Fres.) Rytz, Mitteil. Natur. Ges. Bern. Sitzber page 2, 1923

?=*Phleogena faginea* (Fries) Link., see Carmichael *et al.* 1980.

?≡*Onygena faginea* Fries.

*Onygena apus* Berkeley and Broome, Ann. Nat. Hist. no. 582 see Saccardo, Sylloge Fungorum **8**:862, 1889.

(Collections I have examined under this name have been similar to *O. caprina*).

*Onygena bommerae* Rousseau and Saccardo, Ann. Myc. **11**:322, 1913

(Species uncertain *fide* Rammeloo - based on one presently sterile collection

on feathers of a dead bird; hyphae very similar to *Nannizziopsis vriesii*).

*Onygena mutata* Quelet, Champ. Jura et Vosges 3:449 t.1, f. 6, 1886.

(Saccardo, Saccardo, Sylloge Fungorum **8**:862, 1889.)

=*Amauroascus mutatus*.

*Onygena corvina* Albertini and Schweinitz, 1805 Consp. Fung. p 113, t 9, f 2.

PL 7.14e, 7.15b,c

=*Onygena hysipus* Ditmar in Sturm. Deutschl. Fl. III:15 t 12, 1817 *fide* Fries, 1832.

=*Onygena piligena* Fries, Systema Mycologicum **3**:208, 1832 *fide* Pilat, 1956.

=*Onygena murina* Sommerfelt, Suppl. Fl. Lapp. pg 247, 1826 *fide* Fries, 1832.

=*Onygena corvina* var. *alliacea* Bommer and Rousseau, Mem. Roy. Soc. Bot. Belgium 25:193 see Rammeloo, 1977.

**Ascomata:** in cream or brown or ochre capitulum, 0.9-2mm wide, on apex of solid synnema-like stalk (13mm long and up to 1mm in diam.). **Ascospores:** hyaline to pale yellow-brown, appearing smooth, ovoid or ellipsoidal-cylindric, slightly curved, 2.0-4.0 x 5.0-8.0$u$m. **Asci:** ellipsoidal to globose, 7.0-9.0 x 9.0-14$u$m. **Peridial hyphae:** wall of capitulum white to ochre, smooth, granular or warted; two-layered: outer layer membranous, of large, inflated cells; inner layer filamentous. **Anamorph:** arthroconidia numerous, hyaline, alternate, cylindrical, straight or slightly curved, having a frill at both ends, 3.5-6.5 x 9.5-18$u$m; chlamydospores abundant, variable, 6-10$u$m diam. some conidia terminal, clavate, 4.0-6.0 x 10-18$u$m. **In culture:** [UAMH 3852]. CER 14/25°C yellowish white, irregular growth forming a pinwheel pattern; reverse concolorous. DSA 42/25°C growth very scant, white; reverse pale yellow under inoculum. PYE 14/25°C white, cottony, margin radiately ridged; reverse yellow to orange-brown.

**Notes:** Tubaki (1960) studied the species in culture and referred to the anamorph as "*Coremiella*-like. Samson and Van der Aa (1973) provide a careful developmental study. They report that the size of the fruit body is extremely variable depending on "external circumstances." Fructifications that grow from

darkness to the light often have longer stalks than those formed under full daylight. 'Heads' may vary from 1.5-3mm in diam. The stalk may be 13mm tall. This fungus is not infrequent in the Netherlands, where it is found on feathers, bird nests, bird skulls and wool.

**Material examined: NY** Massee/Feathers/?/ (Drawing); **BR** Rammeloo 5198/?/Nazareth (undetermined natural material); Beeli 604/dead crow/Belgium (remains of bird); **DAOM** 48905/feather/British Columbia (feathers); **MICH** Smith/mouse remains/Michigan (mouse remains); **FH** Thaxter 7320/owl casting/New Hampshire (culture); **UAMH** 3852/wool/culture obtained from CBS.

*Onygena equina* (Wildenow) Persoon Obs. Mycol. **2**:71.

PL 7.12d, 7.13a,b,c, 7.14d>

**Type material:** Possibly no type specimen.

=*Lycoperdon equinum* Wildenow, Fl. Ber. Podr. p 412, t. 7, f. 20, 1787. (Sowerby, Coll. Engl. Fgi. t. 292, 1803.)

=*Onygena caespitosa* Persoon, J. Bot. 2:20, 1809 Plate XV figs 27-35.

**Ascomata:** on apex of cylindrical or flattened stalk, white to cream, yellow or buff, smooth, warted or scaly, up to 1.3cm long and 0.6-1.2mm thick; capitulum white, yellow or brown, smooth, warted or scaly, spherical or globoid or extremely irregular, up to 8mm diam., gregarious or scattered. **Ascospores:** buff to tan, ochre-brown in mass, ellipsoidal, slightly tapered on one end, smooth to slightly roughened, 3.0-5.5 x 5.0-9.0*u*m. **Asci:** subglobose to globose, nonstipitate, arising from croziers and irregularly disposed through vegetative hyphae within the capitulum, 10-14 x 14-22*u*m in diam. **Peridial hyphae:** wall of capitulum two-layered: outer layer 15-120*u*m thick, membranous, of large irregular cells, 4.0-10.5*u*m diam.; inner layer of loosely interwoven hyphae, interwoven hyphae, 60-110*u*m thick. **Appendages:** lacking. **Anamorph:** on simple conidiophores or in synnemata; hyaline terminal aleurioconidia or arthroconidia, cylindrical or ellipsoidal, truncate, smooth 3.5-7.0 x 5.0-12.0*u*m. **In culture:** [UAMH 3829]. CER 21/25°C white, granular; reverse yellowish. DSA 42/25°C growth yellowish, localized in knots in centre; reverse concolorous. PYE 21/25°C rosy buff, granular, slightly cracked; reverse yellowish orange.

**Notes:** Strongly keratinolytic. Specimens in Herb. E contain artificially inoculated substrata including human toenails, horn, hoof, hedgehog spines. Generally larger than *Onygena corvina*. When grown on keratin from horse hoof, cultures produced sterile stipitate structures to 8mm in height with the outward appearance of being fertile stromata as found in nature.

Both species are very variable in the shape and form of the stromata.

**Material examined:** (In the following list "-" indicates that the material on which the specimen was found was either hoof or horn). **ANSM** Menke/-/?; Menke 39/-/Germany?; **BP** 41923/-/Hungary; **BR** ?/-/? (4 specimens); Herb. Westendorp/-/?; M434/-/? M664/-/? Rel. Libert./-/Malmedy; Roumeg 307/wool hat/France (3 specimens); 1074/-/?; XXXIX/-/?; **DAOM** 122143/-/Michigan; 124593/owl pellet/N.W.T; 124667, 124668/muskox horn/N.W.T; 132754/-/Quebec; 133958/muskox pellets/N.W.T.; 150873/-/Hungary; 5271, 56538, 84949, 86836, 87230, 154836/-/Quebec; 36534/-/Sweden; 37457, 37458/-/Ontario; 59086/-/?Vogeso Rhen.; 62734/-/B.C.; **DBN** Mougeot 775/-/?; Roumeg. 1677/-/France; Roumeg. 307/old hat/France (as variety *"caespitosa"*; **E**Hend. 4121, 9143/-/Britain; J.T. Palmer/assorted natural keratins/?; Moug. and Nest. 775/-/? (3 specimens); 1034/sheep carcass/Scotland; 183/-/Scotland (3 specimens); **FH** ?/-/Vermont; ?/?; ?/-/Michigan; ?/?; ?Peck/-/Floodwood; ?1326/-/?; ex Herb J. Lind/-/Denmark?; ex Herb. Kew/-/England; Herb. Bartholemew/-/? J. Faull 7116/-/Mass.; THAX? 1027, 2765/-/Conn.; THAX 1202/-/?; White 1646/?/New York; THAX? 1026/-/Conn. (giant form); Lloyd 6984/-/Canada (Patouillard); 551/S5355/-/Leveille? (Patouillard); **LE** ?/-/Petropol? (2 specimens); date, 1893/-/Uppsala; date, 1898/woolen fabric/USSR?; ex Herb. Wiatkansis/-/USSR; Herb. Weinmann/-/?; Holls Schmidt XXXIX/-/Germany; Rabenh. 2338/?/Baltra? (2 specimens); 1074/-/Morthier?; 645/-/Germany; 775/-/Vogeso-Rhen. 780/-/Sweden; 86/?/?; **MICH** Drummond/-/Michigan; Fitzpatrick/-/New York; Harrison 11868/-/Nova Scotia; Kauffman/-/New York; Smith/baseball(!)/Washington; Smith/-/Michigan; Ellis 75/-/Ontario; **NY** H.J. Banker?/-/New York (2 specimens); H. J. Banker 1326/-/New York; Karsten 178/-/Finland; Massee/?/?; Mougeot 775/-/Vogeso-Rhen; NYBG,

1821/-/England; NYBG 65-118/-/New York; Roum. 307, 4913/-/France; Sturgis/-/Colorado; 1326/-/New York; **NYS** C. H. Peck/-/New York? (2 specimens); G. W. Clinton/-/New York (2 specimens); H. J. Banker/-/New York (2 specimens); Macoun/-/Ottawa; Patouillard/-/France; C. H. Peck/-/New York (large squat form); Roum. 1677/-/France; **PAV** Fuckel 1074/?/?; 307/-/Vosges?; 645/-/Germany; 775/-/?; **TRTC** ?/-/Maine; Banker/-/New York; Coll. Emmons/-/Quebec; Coll. Jackson/-/New York; Macoun/-/Ontario; 42988/-/Ontario **UAMH** 3829/cow hoof/obtained from CBS; **UPS** Banker/-/New York; Degelius/-/Sweden. as *Leptostromatacearum crandali*: **NY** San Juan Mountains/-/California. as *Lycoperdon equinum*: **E** Brodeis?/-/?. as *Onygena caprina*: **HBG** O. Jaap/-/?. as *Onygena piligena*: **BR** 762/old wool bonnet/France (2 specimens); **E** Wat. 38/owl pellet/Scotland; (possibly an error); **S** Quelet?/owl pellet/France? (2 specimens);Straper/rotten matting/Sonntagberg?; Romell. 1587/?/?; as *Onygena* sp.: **NYS** C. H. Peck/-/New York.

**PECTINOTRICHUM** Varsavsky and Orr, 1971

Mycopathol. et Mycol. Appl. **43**:229.

**Type species:** *Pectinotrichum llanense* Varsavsky and Orr.

**Ascomata:** yellowish white when young, brown at maturity, globose, 250-450*um* diam. **Ascospores:** hyaline or pale yellow, globose to ovoid, smooth, 2.8-3.5 x 3.1-3.5*um* **Asci:** globose, 4.2-5.4*um*, 8-spored. **Peridial hyphae:** septa enlarged, wall thick and tuberculate, 3.0-6.7*um* diam. **Appendages:** pectinate, curved, bifurcate or truncate; long appendages brown, asperulate to tuberculate, septate, straight, spine-like with pointed apices 30-70*um* long, 5.5-9.0*um* wide at base. **Anamorph:** aleurioconidia. **Degrades:** keratin.

**Notes:** Varsavsky and Orr *op. cit.* suggest that this species is closely related to *Auxarthron* due to the presence of knuckle joints and elongate appendages; and to *Ctenomyces* because of keratinolytic capacities. They also suggest that *Pectinotrichum* might be an evolutionary forerunner of *Arthroderma*. I agree that it is probably closely related to *Auxarthron*.

Von Arx (1981a) suggests that the genus *Pectinotrichum* is synonymous with

*Gymnoascus*. I have chosen to regard *Pectinotrichum* as a genus separate from others in the Onygenaceae. Morphologically it is closest to *Auxarthron*. It is maintained separate from *Auxarthron* due to the morphology of the anamorph which is a *Chrysosporium* rather than *Malbranchea*-like. The unusual pectinate organs on the peridium are also not found in any species of *Auxarthron*.

*Pectinotrichum llanense* Varsavsky and Orr, 1971 Mycopathol. et Mycol. Appl. **43**:231 FIG 1-8.

FIG 7.13, PL 7.9b

**Type material:** HOLOTYPE (*cultura desiccata*) **NY** LL8 (savannah soil, Venezuela).

**Ascomata:** pale yellow, becoming pale brown at maturity, 350-450*um* diam. excl. appendages. **Ascospores:** pale yellow, smooth to very slightly roughened, oblate 2.58-3.0 - 3.1 x 3.5*um*. **Asci:** globose, evanescent, 8-spored. **Peridial hyphae:** reticulate, enlarged at septa, mostly 3.5-4.0*um* wide, pectinate formations directed toward the outside of the peridium. **Appendages:** long appendages - brown, tuberculate at base, apex smooth, curved or bent, flexuous with with many long lateral branches 550-590*um*, 7.5-10.5*um* at base; short appendages dark brown, tuberculate, straight and spine-like with pointed apices, 30-70*um* long and 7.4-8.5*um* wide at base. **Anamorph:** hyaline, smooth, bluntly pointed, pyriform aleurioconidia "of the *Chrysosporium* type" *fide* Varsavsky, 1.5-2.3 x 4.8-7.2(8)*um*. **In culture:** [UAMH 3400]. CER 49/25°C cream, radiately fibrillose; reverse pale yellow; DSA 49/25°C abundant, dense, cream-colored mycelium, at hair, numerous light brown ascomata; PYE 49/25°C cream colored, zonate, dense growth, surface cracked; reverse orange-brown.

**Notes:** Known only from material isolated in Venezuela (7 isolates).

**Material examined:** **NY** (type as cited); O-779 (=UAMH 3401), O-3160 (=UAMH 3400)/soil/Venezuela; O-3501 (=UAMH 3447)/human/?.

**RENISPORA** Sigler and Carmichael, 1979

Mycotaxon **10**:133-134.

**Type species:** *Renispora flavissima* Sigler, Gaur, Lichtwardt and Carmichael

**Ascomata:** yellow, spherical, to 200*um* diam. (100-150*um*) surrounded by wefts of hyphae with *Chrysosporium* conidia heterothallic. **Asci:** mostly clavate, hyaline, 6.0-10*um*, 8-spored. **Ascospores:** reniform or bacilliform, finely pitted, hyaline or yellow at maturity ±1-2 lipid droplets, mostly 2.5 x 4.0-5.5*um*. **Appendages:** lacking. **Peridial hyphae:** poorly differentiated from vegetative hyphae, compactly intertwined, thin-walled, narrow, smooth or encrusted, hyaline or yellow. **Ascocarp initials:** hyaline, coiling about each other. **Anamorph:** *Chrysosporium*. **Degrades:** keratin.

**Notes:** Ascospores are very similar to those of *O. equina* in sculpturing and in the presence of guttules.

*Renispora flavissima* Sigler, Gaur, Lichtwardt and Carmichael, 1979 Mycotaxon **10**:133-134.

7.15a, 7.19b

**Type material:** HOLOTYPE (*cultura desiccata*) **UAMH** 4205 (bat guano, Kansas)

**Anamorph name:** *Chrysosporium* state of *Renispora flavissima*.

**Ascomata:** yellow, spherical, 30-200*um*. **Ascospores:** reniform, or bacilliform, finely pitted, yellow at maturity often having 1 or 2 lipid droplets (2.2-)2.5(-3) x 4-5.5*um*. **Asci:** short-stipitate, clavate, max. diam. not exceeding 10*um*. **Peridial hyphae:** hyaline to yellow, poorly differentiated, thin-walled, narrow, smooth or encrusted. **Appendages:** lacking. **Anamorph:** aleurioconidia terminal ellipsoid to pyriform, becoming globose or subglobose, spiny, 6-11(13)*um* diam., sessile or on short or long branches. 2 or 3 forming in succession; some arthroconidia. **In culture:** [UAMH 4210]. CER 28/25°C yellow to fawn, granular in centre; reverse concolorous. DSA 48/25°C orange or brownish yellow with discrete knots in centre; reverse concolorous. PYE 28/25°C bright golden yellow, granular; reverse dark orange- brown.

**Notes:** Keratinolytic, non-pathogenic, found only in bat guano and soil. Anamorph closely resembles the *Chrysosporium* state of *Ajellomyces capsulatus*. Gaur and Lichtwardt (1980) present an SEM study of conidiogenesis.

**Material examined: UAMH** 4140, 4141/bat guano/Kansas; 4184, 4185, 4187, 4191/bat soil/Kansas.

SHANORELLA Benjamin, 1956

Aliso 3:319.

**Type species:** *Shanorella spirotricha* Benjamin.

**Ascomata:** bright yellow to golden yellow, globose, thickly aggregated in cottony tufts, densely covered in white superficial mycelium. **Ascospores:** bright yellow, flattened, oblate, smooth or minutely roughened, <4*um* maximum diam. **Asci:** hyaline, globose. **Peridial hyphae:** pale yellow, septate, thick-walled, smooth cells irregular, disarticulating at maturity, elongate; forming an incompositothecium. **Appendages:** hyaline, septate, thin walled, slender, tips coiled. **Ascocarp initials:** coils. **Anamorph:** hyaline arthro- and aleurioconidia. **Degrades:** keratin.

**Notes:** The incompositothecium resembles that of some *Gymnascella* species (e.g. *G. nodulosus*). The ability to break down keratin and the pitted ascospores are sufficient to place *Shanorella* in the Onygenaceae.

*Shanorella spirotricha* Benjamin, 1956 El Aliso **3**:319-321.

FIG 7.14, 19a,d,e

**Type material:** HOLOTYPE (*cultura desiccata*). **RSA** 156 (feathers of a dead bird, California).

**Ascomata:** white at first, becoming yellow, grayish yellow or bright yellow, 100 - 600*um* diam., globose, confluent or solitary, often gregarious under a common tomentum. **Ascospores:** bright yellow, oblate, thick-walled, 2.2-2.8 x 3.5-4.2*um*, minutely roughened. **Asci:** 5.2-7.8*um*, globose, evanescent, 8-spored. **Peridial hyphae:** pale yellow, septate, cells 3-15 x 10-35*um* or more, straight, curved, simple or branched, nodulose, contorted, thick-walled (0.5-2.0*um*). **Appendages:** fine, hyaline septate, helices, 1-1.3*um* wide, with 20-30 gyres; helices may be 10-20*um* wide and 25-40*um* long, and originate as terminal or lateral outgrowths of peridial hyphae.Helices abundant, scarce or absent depending on strain. **Ascocarp initials:** robust irregular, septate coil, 15*um* in length. **Anamorph:** terminal, lateral or intercalary, clavate or oblong conidia, 2.0-3.3 x 3.3-12*um*, **In culture:** [UAMH 4765]. CER 21/25°C bright citrine yellow, with green tint in older portions, margin white, granular; reverse pale

yellow. DSA 43/25°C greenish or brownish yellow in discrete knots; reverse concolorous. PYE 21/25°C white, cottony with pale yellow knots; reverse concolorous.

**Notes:** Since Benjamin's description of this species in 1956, there have been no further reports of its occurrence. I have found *S. spirotricha* to be one of the most common ascomycetes on carnivore dung particularly, after at least four months of incubation. On natural materials, this species can form very large conglomerations of ascomata within a matrix of vegetative hyphae. These stromatic formations may be up to 2 cm or more in diam.

**Material examined: RSA 156** (type as cited); 65 (=UAMH, 1970)/chicken feathers/Illinois; 1424 (=UAMH 3116)/owl pellet/Utah; **RSA** 1517/owl pellet/California; **NY** O-1009/soil/England; as *Arachniotus* sp.: **TRTC** 35218/carnivore dung/Ontario; as *Gymnoascus* sp.: **TRTC** C1197/rodent dung/Alberta; **UAMH** 4764/carnivore dung/Alberta; 4765/weasel dung/Alberta; 4772/coyote dung/Alberta.

**SPIROMASTIX** Kuehn and Orr, 1962

Mycologia **59:**160.

**Type species:** *Spiromastix warcupii* Kuehn and Orr.

**Ascomata:** brown, ovoid to spherical, 50-100*u*m diam. excl. appendages. **Ascospores:** smooth, pale yellow-orange, ovoid, small, 2.0-2.5 x 2.5-2.9*u*m. **Asci:** ovoid, 5-5.7 x 7-7.7*u*m, 8-spored. **Peridial hyphae:** interwoven, branched, delicate, thin-walled, smooth, pale yellowish brown hyphae, 1.5-2.2*u*m diam. **Appendages:** dark yellow, curved, unbranched, smooth-walled, slender and of ±uniform diam., walls approx 1*u*m thick. **Anamorph:** unknown. **Degrades:** keratin.

**Notes:** This is a beautiful genus which is known only from the type collection. The thick-walled, yellow, scimitar-shaped appendages resemble the disarticulated cells of *Shanorella spirotricha* in overall appearance.

*Spiromastix warcupii* Kuehn and Orr, 1962 Mycologia **54:**160 FIG 1-3.

PL 7.16d, 7.17b,d

**Type material:** TYPE STRAIN **UAMH** 1668 (wheatfield soil, Australia) (Possibly

no holotype designated).

**Ascomata:** brown, ovoid to spherical, 50-100*um* diam. incl. appendages. **Ascospores:** light yellow, oblate, smooth, 2.0-2.5 x 2.5-2.9*um*. **Asci:** ovoid, 5-5.5 x 7-7.7*um*. **Peridial hyphae:** pale yellow-brown, closely interwoven, thin-walled, smooth, 1.5-2.2*um*. **Appendages:** dark yellow, smooth, thick-walled, slender, loosely curved, 1.1*um* diam. **Ascocarp initials:** small, variable, always arising from different parent hyphae. **Anamorph:** unknown. **In culture:** [UAMH 1668]. CER 42/25°C white, felty; reverse orange-brown. DSA 42/25°C white with brown central region (from cleistothecia); reverse yellow to cream. PYE 42/25°C pale yellowish white, dense; reverse orange-brown.

**Material examined:** Known only from the type. **NY, RSA, UAMH** 1668 (type as cited, =RSA 1293).

**UNCINOCARPUS** Sigler and Orr, 1976

*apud* Sigler and Carmichael, Mycotaxon **4**:462-464.

**Type species:** *Uncinocarpus reesii* Sigler and Orr.

**Ascomata:** reddish brown, globose, to 1000*um* diam. **Ascospores:** yellow-brown to red-brown, oblate, sometimes with a depression on one face, smooth, 2.5-3 x 4-5*um*. **Asci:** hyaline, short-stalked, subglobose, 7-9*um*, 8-spored. **Peridial hyphae:** reddish or orange-brown, roughened, thick-walled, and forming a reticuloperidium; or absent beyond the formation of thick-walled ±branched appendages. **Appendages:** red-brown, aseptate, smooth, thick-walled, occasionally helical, ±lateral, uncinate branches, 5-8*um* wide, tips wide, uncinate. **Ascocarp initials:** hyaline septate branches with bulbous enlarged tips often completely inrolled. **Anamorph:** intercalary and terminal conidia. **Degrades:** keratin.

**Notes:** I have transferred *Gymnoascus uncinatus* here due to the similarities in appendage morphology and ascospore morphology. *Uncinocarpus uncinatus* is quite different from *Gymnoascus reessii* due to these Onygenalean characteristics. *U. reesii* and *U. uncinatus* may be quickly distinguished on the basis of the appendages; those of *U. uncinatus* are thick and wide to the distal end and those of *Uncinocarpus reesii* taper to a point.

*Uncinocarpus reesii* Sigler and Orr, 1976 Mycotaxon **4**:349-388, FIG 20A-K and 21A-J.

FIG 7.15, PL 7.16a, 7.18c,e

**Type material:** HOLOTYPE **UAMH** 3882 (feathers, Australia).

=*Gymnoascus siglerae* Von Arx, 1981a.

**Ascomata:** reddish brown, ±globose, 200-1000*u*m diam. excl. appendages, discrete. **Ascospores:** yellow-brown, reddish brown, minutely punctate, oblate, sometimes one face depressed, 2.5-3.0 x 4.0-5.0*u*m. **Asci:** evanescent, ±globose, 7.0-9.0*u*m diam., 8-spored. **Peridial hyphae:** lacking beyond the loosely intertwined appendages. **Appendages:** 100-250*u*m in length, uncinate, aseptate, pale brown, becoming slightly wider at the tip, 5.0-8.0*u*m. **Ascocarp initials:** heterothallic; short, septate branches, tip enlarged bulbous and often completely inrolled. **Anamorph:** arthroconidia hyaline becoming tan, barrel-shaped or cylindrical if intercalary; produced in association with uncinate appendages, smooth, mostly 2.5-3.5 x 3.5-6.0*u*m **In culture:** [UAMH 3881]. CER 14/25°C yellowish, granular; reverse pale yellow. DSA 42/25°C irregular distribution brown knots of mycelium over a pale brown mat in vicinity of hair; reverse buff. PYE 14/25°C pale beige, slightly cottony; reverse orange yellow at margin.

**Notes:** Anamorph is frequently isolated during surveys of soil and keratinous materials. The teleomorph was described but never named prior to the treatment of Sigler and Orr (in Sigler and Carmichael, *op. cit.*) Von Arx (1981a) placed the type of *Uncinocarpus* in *Gymnoascus*. The punctate ascospores, keratinolytic capacities and the well-developed anamorph of *U. reesii* support its disposition as the type of a genus distinct from *Gymnoascus*.

**Material examined: UAMH** (*Malbranchea* state of *Uncinocarpus reessii*) S160 (Emmons C3716)/*Silvilagus* sp./Texas; 1273/soil/Venezuela; 1704, 1706/soil/California; 1955/soil/Argentina; 2002, 2050, 2852, 2854, 3573, 3819, 3820/soil/Italy; 2845, 2862, 3484, 3485/feathers/Australia; 2855/soil/Hungary; 2991, 2992/clinical source/West Virgina; 3257, 3258/soil/India; 3703/soil/Utah; 3843/feathers/Czechoslovakia; 3846/nest/Czechoslovakia; 3881/-SAC from type.

*Uncinocarpus uncinatus* (Eidam) comb. nov. .

FIG 7.16, PL 7.5d, 7.16b, 7.18a,b,d

**Type material:** PROPOSED NEOTYPE (*cultura desiccata*) **RSA** 56 (dung, California).

=*Gymnoascus uncinatus* Eidam, Cohn, Beit. Biol. Pfl. **3**:292, 1880 Taf XV, FIG 35-42. (Basionym).

=*Myxotrichum uncinatum* (Eidam) Schroeter, KryptogamenFlora von Schlesiens **3**:212, 1893.

**Ascomata:** yellow to orange-brown to red-brown, globose, 150-1150*u*m diam. **Ascospores:** yellowish, oblate, 1.5-3.2 x 1.5-5.5*u*m. **Asci:** globose to ovoid, 6.0-9.8*u*m diam. **Peridial hyphae:** orange, reddish orange, smooth to roughened, interwoven, with a few blunt free ends. **Appendages:** orange to reddish orange to brownish yellow, aseptate, 5.0-8.8 x 75-387*u*m, uncinate, rarely branched, walls at base to 3.0*u*m thick, remaining robust and wide to the distal end. **Ascocarp initials:** swollen antheridium surrounded by an ascogonial coil. (mutually coiled equal gametangia, 23*u*m long when coiled *fide* Benjamin, 1956). **Anamorph:** asperulate to minutely echinulate, terminal aleurioconidia and intercalary arthroconidia, 3.0-4.2 x 3.8-6.8*u*m; becoming yellowish and thick-walled with age. **In culture:** [UAMH 3913]. CER 14/25°C pale yellow irregularly and sparsely felty; reverse orange brown in centre paling at margin. DSA 42/25°C yellowish white knots in vicinity of hair; reverse pale yellow. PYE 14/25°C yellow, cottony; reverse yellow to yellowish orange.

**Notes:** This is a striking species because of the numerous, wide, uncinate appendages adorning the reticuloperidium. It resembles *Auxarthron californiense* which also has well developed uncinate appendages. However, the ascospores of *A. californiense* have very broad puncta which are easily noted under the oil immersion lens. The ascospores of *U. uncinatus* appear almost smooth. Massee and Salmon (1902) noted that the spores of an isolate they called *Gymnoascus uncinatus* were minutely "asperous", possibly indicating that they were looking at *A. californiense*. Van Oorschot (1981) labelled the anamorph "*Chrysosporium merdarium*." but the conidia appear quite different to me and apparently have no binomial.

**Material examined:** **UAMH** 3913 (strain derived from proposed neotype). **FH, TRTC** Thaxter 509/chicken dung/Connecticut; Thaxter 591/dog dung/Connecticut; **MICH** Povah?/deer dung/Michigan; **RSA** 56/(proposed neotype as cited); 425/owl pellet/California; 460/frog(?) dung/California; as *Gymnoascus* sp.: **FH, TRTC** Piquet/chicken bones/Mass. as *Myxotrichum* sp. or *Myxotrichum uncinatum*: **DAOM** 12409/rat dung/Kansas; **TRTC** 66.3172c/Hyrax dung/Uganda; 6537/dung/Ontario; 38215/carnivore dung/Ontario; Nashville/raccoon dung/Ontario.

**XYNOPHILA** Malloch and Cain, 1971
Can. J. Bot. **49**:845-846.

**Type species:** *Xynophila mephitalis* Malloch and Cain

**Ascomata:** clustered within a dense, white, tomentose layer of hyphae; orange or brown, subglobose to globose, 150-300*um* diam. **Ascospores:** oblate, yellow to yellow-brown, 2.0-3.0 x 3.0-4.0*um*, smooth to minutely roughened. **Asci:** subglobose to globose, 6-12*um* diam. borne on croziers, 8-spored. **Appendages:** lacking. **Peridial hyphae:** membranous layer of reddish brown, polygonal cells. **Anamorph:** smooth, hyaline arthroconidia 2.0-5.0 x 5.0-15*um*, pyriform to cylindrical or irregular in shape, non-septate to multiseptate, simple or branched, hyaline or smooth; infrequent. **Degrades:** keratin.

**Notes:** This genus appears to occupy a transitional position between *Onygena* cleistothecial species, such as *Aphanoascus* and *Keratinophyton*. It forms many individual cleistothecia within a woolly mass of hyaline vegetative hyphae. The entire structure may be regarded as a stroma. *Ascocalvatia* is similarbut the ascospores of *A. alveolata* are cylindrical rather than oblate.

*Xynophila mephitalis* Malloch and Cain, 1971 Can. J. Bot. **49**:845-846 FIG 1-10.

<u>FIG 7.17, 3.1d, 7.9a, 7.17a,c</u>

**Type material:** HOLOTYPE (*cultura desiccata*) **TRTC** 42886 (wolf dung, Ontario).

**Ascomata:** yellow-orange to brown, globose, 50-300*um* diam. clustered within

a white arachnoid mass of hyphae. These compound structures may be up to 1cm diam. **Ascospores:** yellow-orange to orange brown, smooth to minutely roughened, 1.8-3.0 x 3.0-4.0*um*, conglobate. **Asci:** globose to subglobose, 6.0-12*um*, 8-spored. **Peridial hyphae:** orange-brown, cells 2.0-4.0 x 3.0-20*um*, forming a membranous layer; outer hyphal covering white and most developed on natural substrate; poorly differentiated when grown on agar cultures. **Anamorph:** arthroconidia pyriform to cylindrical, 0-multiseptate, simple or branched, smooth, 2.0-5.0 x 5.0-30*um*, not numerous. **In culture:** [UAMH 3849]. CER 21/25°C orange brown to buff brown, concentrically zonate; reverse yellowish brown. DSA 42/25°C greenish buff localized in vicinity of hair; reverse yellowish orange. PYE 14/25°C yellowish cream, velvety growth; reverse orange-brown. (Ascomata formed in abundance on OAT).

**Notes:** This distinctive species is first detected by the strong skunk-like odour that it produces. It forms small, white tufts on the surface of dung samples; the tufts may eventually be 1cm diam. On agar media, these complex structures do not form. Instead, the membranous cleistothecia form individually.

**Material examined: TRTC** 42886, (holotype as cited); 45338/raccoon dung/Ontario; 32268/skunk dung/Ontario; **UAMH** 3849 (type strain as cited).

Figure 7.1. *Ajellomyces dermatitidis* (drawn from published descriptions).

**a** Ascoma with broad helices originating from centre of ascoma and giving rise to peridial hyphae which are swollen between septa. X330.

**b** *Zymonema* state; globose, vegetative cells of yeast phase. (Redrawn from Emmons *et al.* X1250.

**c** *Chryosporium dermatitidis*. Solitary, pyriform aleurioconidia. X1330.

**d** Minute, spherical, punctate ascospores. X10345.

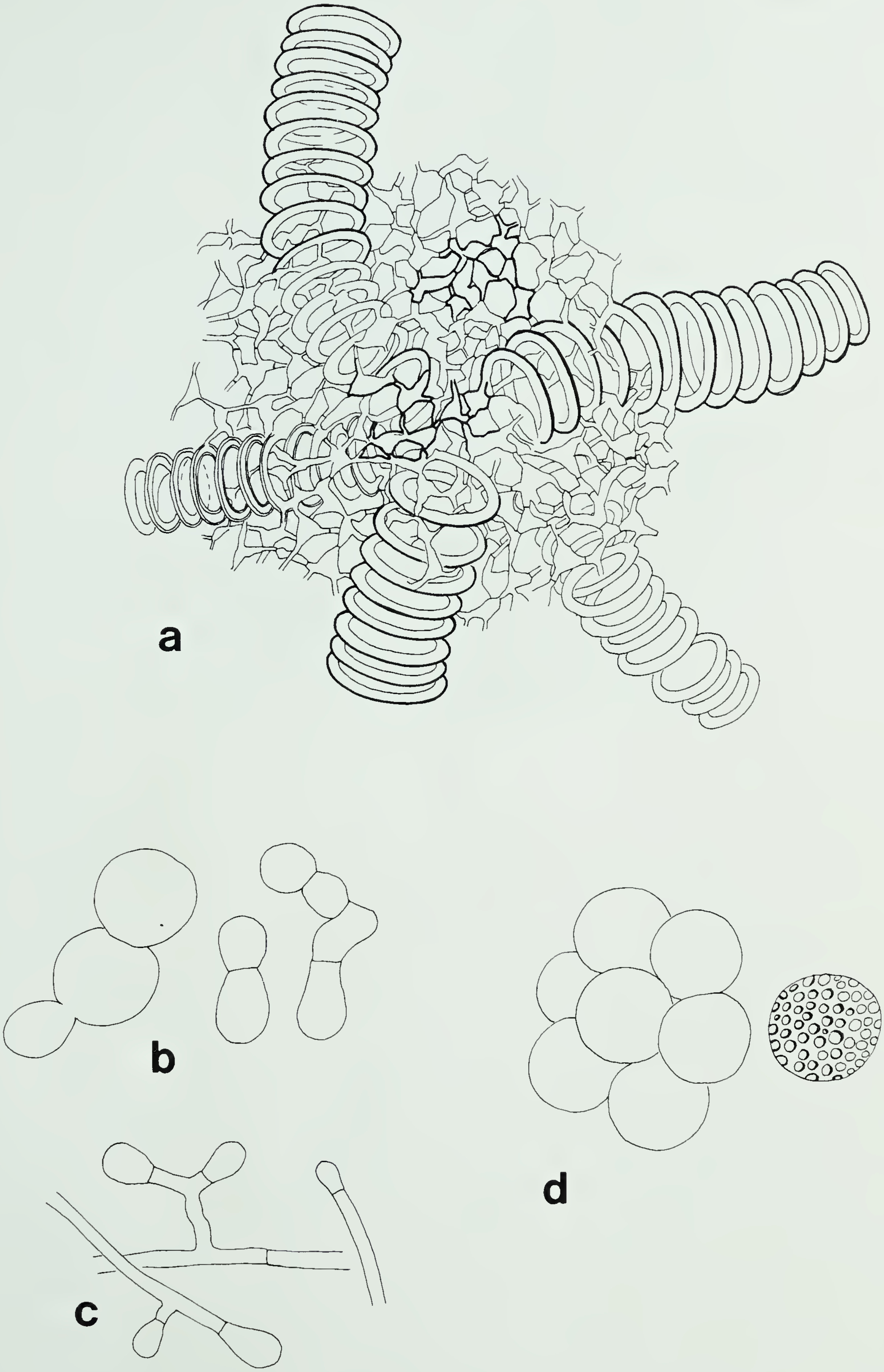

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Figure 7.2. *Aphanoascus canadensis* (UAMH 4574).

**a** Ascoma with cleistoperidium wall. X215.

**b** Anamorph of arthro and aleurioconidia. X1850.

**c** Ascus and individual, oblate ascospores (individual spores show punctum pattern). X5750.

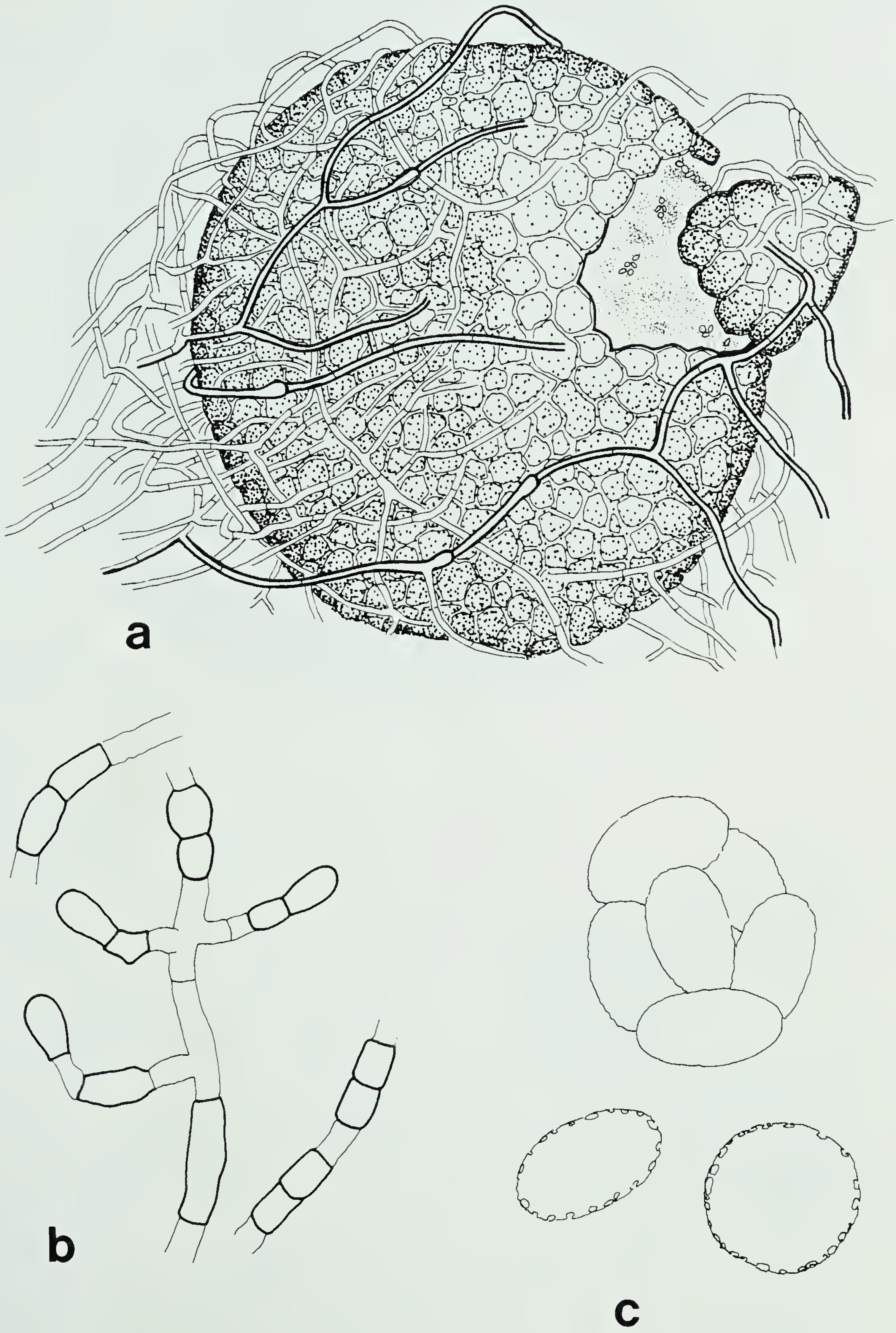
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Figure 7.3. *Aphanoascus fulvescens* (UAMH 4603).

**a** Ascoma (cleistoperidium) with membranous wall. X450.

**b** Anamorph of solitary aleurioconidia, long- or short- pedicellate, pyriform with a truncate base. X1455.

**c** Ascospores and ascus; ascospores look "spiny" as a result of the dense arrangement of irregular pits. X3715.

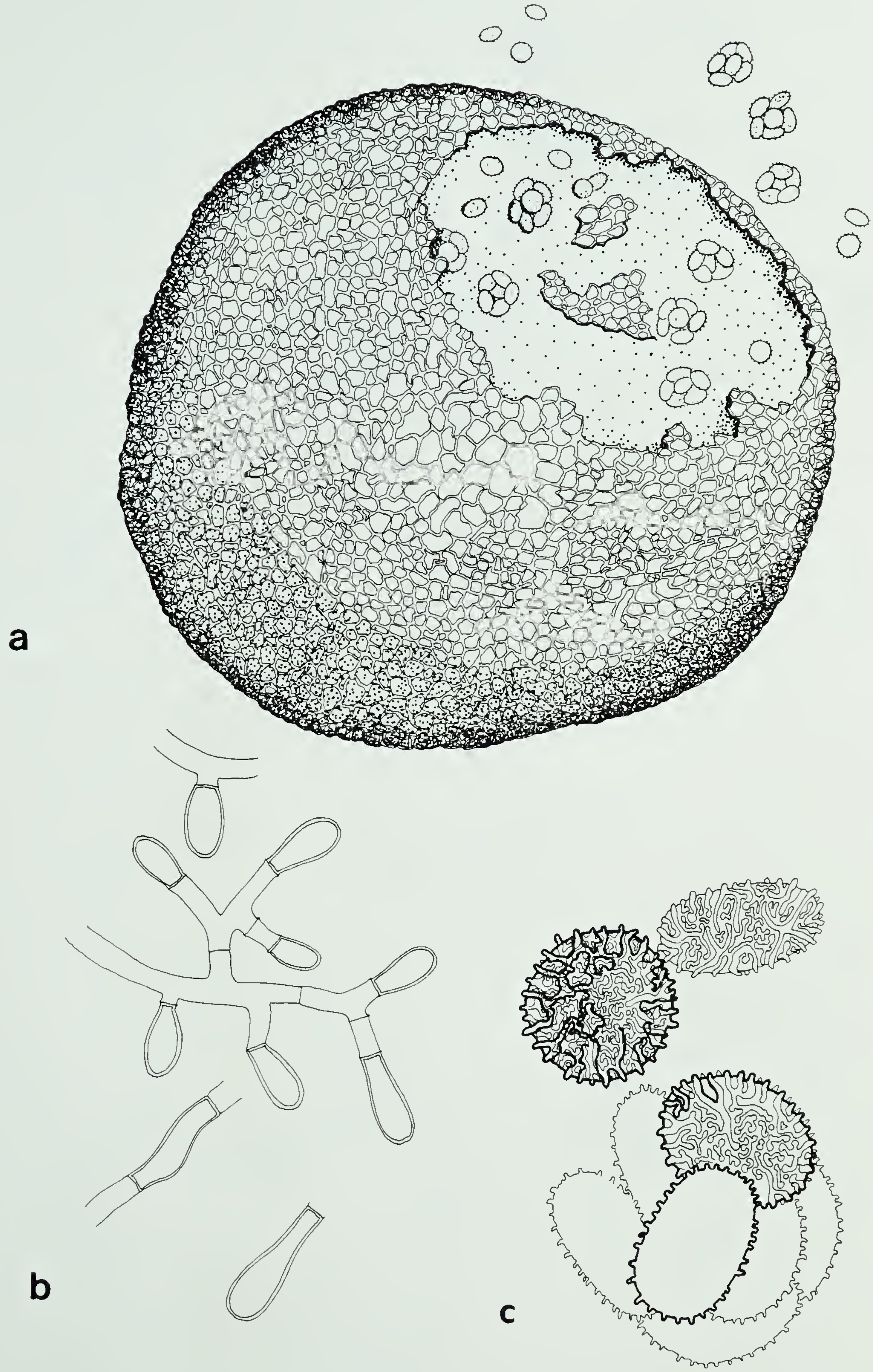
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Figure 7.4. *Auxarthron californiense* (RSA 1525).

**a** Ascoma with uncinate appendages with pronounced knuckle joints. X540.

**b** Anamorph of intercalary and terminal conidia. X2180.

**c** Ascospores with broad pits; appearing reticulate. X6425.

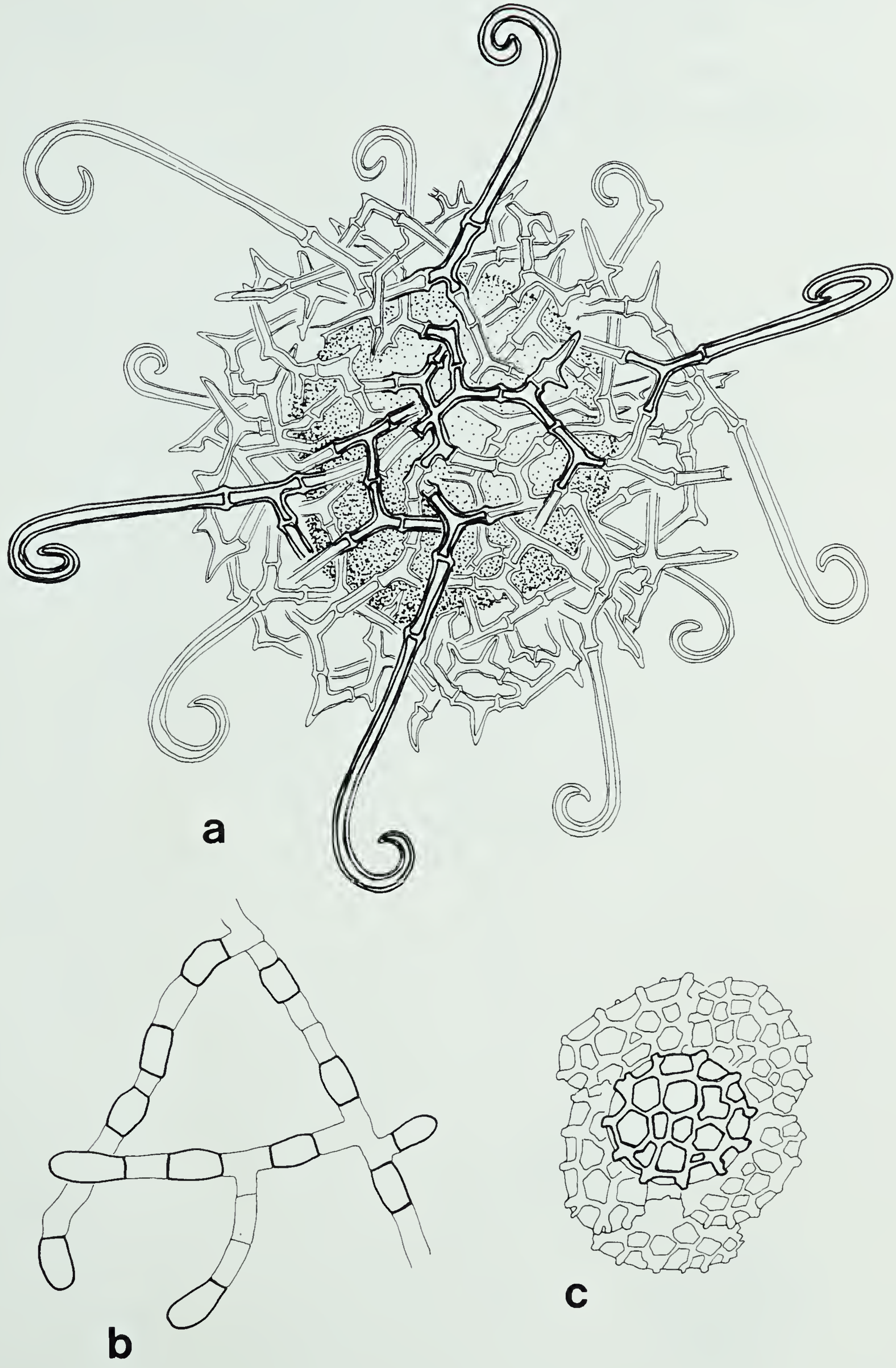
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Figure 7.5 *Auxarthron compactum* (NY O-573).

**a** Ascoma with short, broad, thick-walled peridial cells. X500.

**b** Oblate, punctate-reticulate ascospores. X8000.

Anamorph not illustrated.


a
b

Figure 7.6. *Auxarthron conjugatum* (NY O-520).

**a** Ascoma showing reticuloperidium of thick-walled cells, and long appendages, some with bifurcate tips. X510.

**b** Arthroconidia on lateral arcuate branches. X1665.

**c** Finely punctate-reticulate, oblate ascospores. X6875.

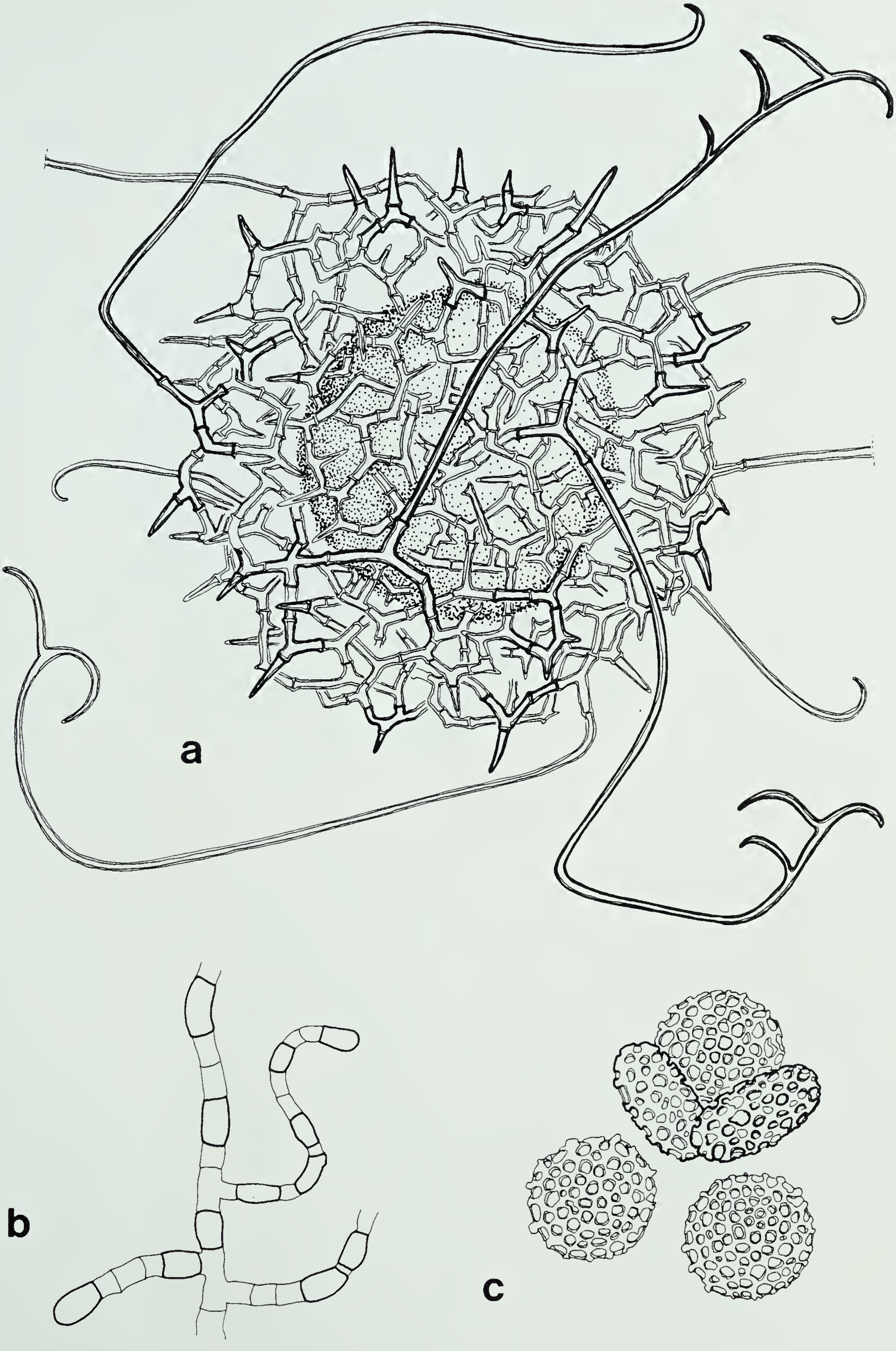
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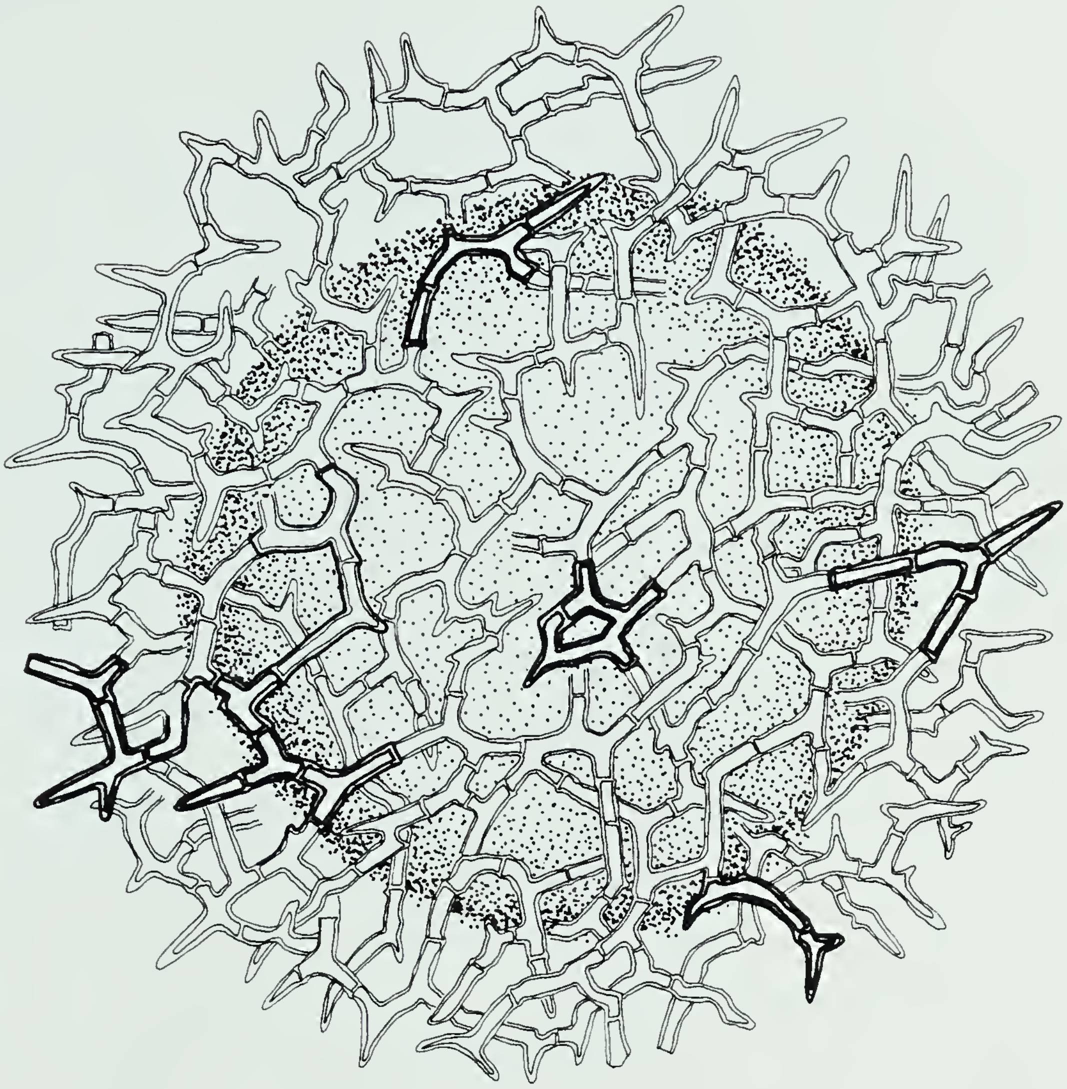
Figure 7.7 *Auxarthron reticulatum* (UAMH 1585).

a Ascoma showing reticuloperidium of thick-walled cells. X610.

b Anamorph of intercalary and terminal conidia. X1605.

c Globose, punctate-reticulate ascospores in ascal cluster. X8665.



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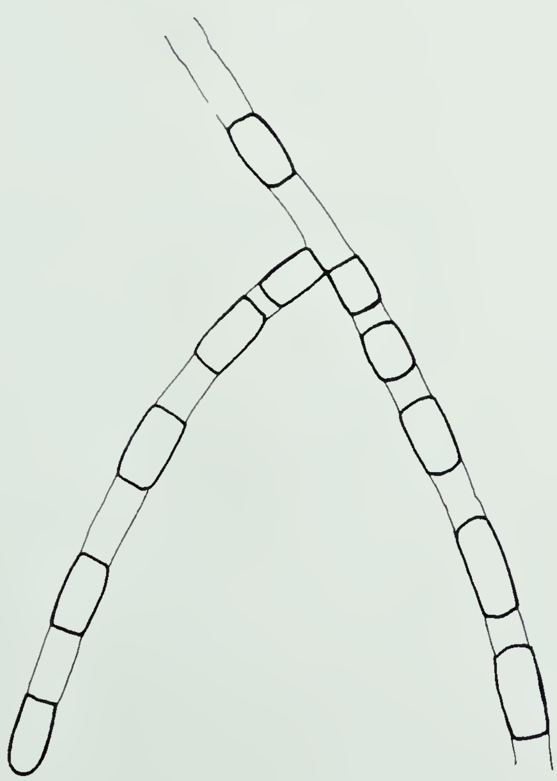

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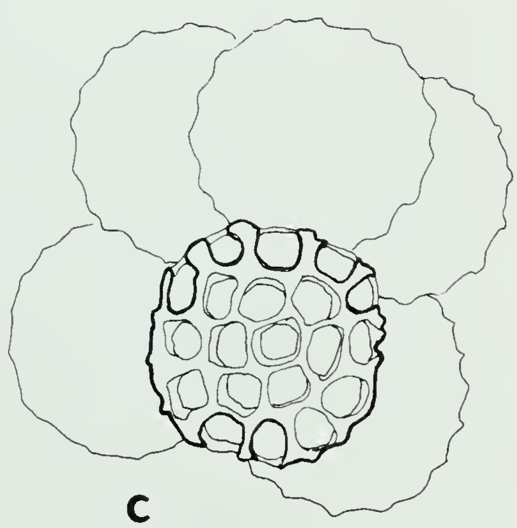


c

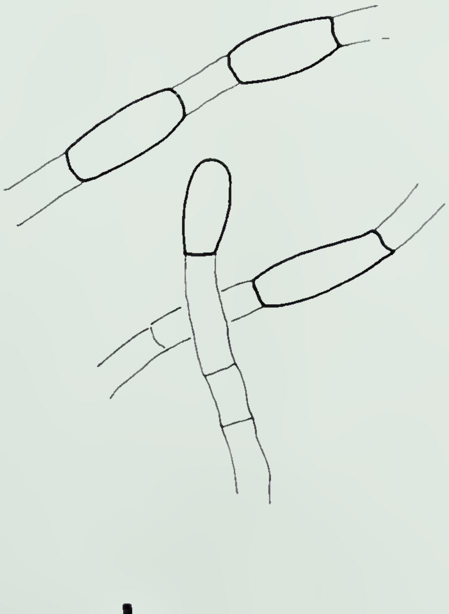
Figure 7.8. *Auxarthron zuffianum* (RSA 517).

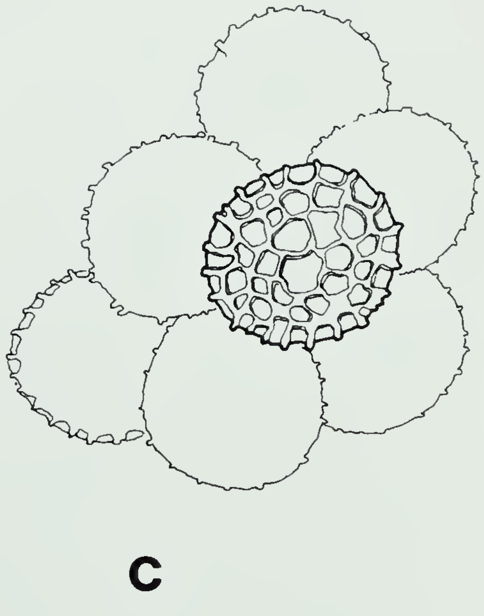
**a** Reticulothecium with short, spine-like, straight or curved appendages. X800.

**b** Cylindrical or oblong arthroconidia. X1500.

**c** Globose to subglobose, punctate-reticulate ascospores showing polygonal arrangement in ascal cluster. X7330.

a





c

b

Figure 7.9. *Keratinophyton durum* (UAMH 856).

**a** Cleistothecial ascoma with membranous wall. X875.

**b** Anamorph of smooth-walled, clavate, sessile conidia. X1545.

**c** Thick-walled, oblate ascospores with symmetrical, wide, punctate equatorial crest. X5625.

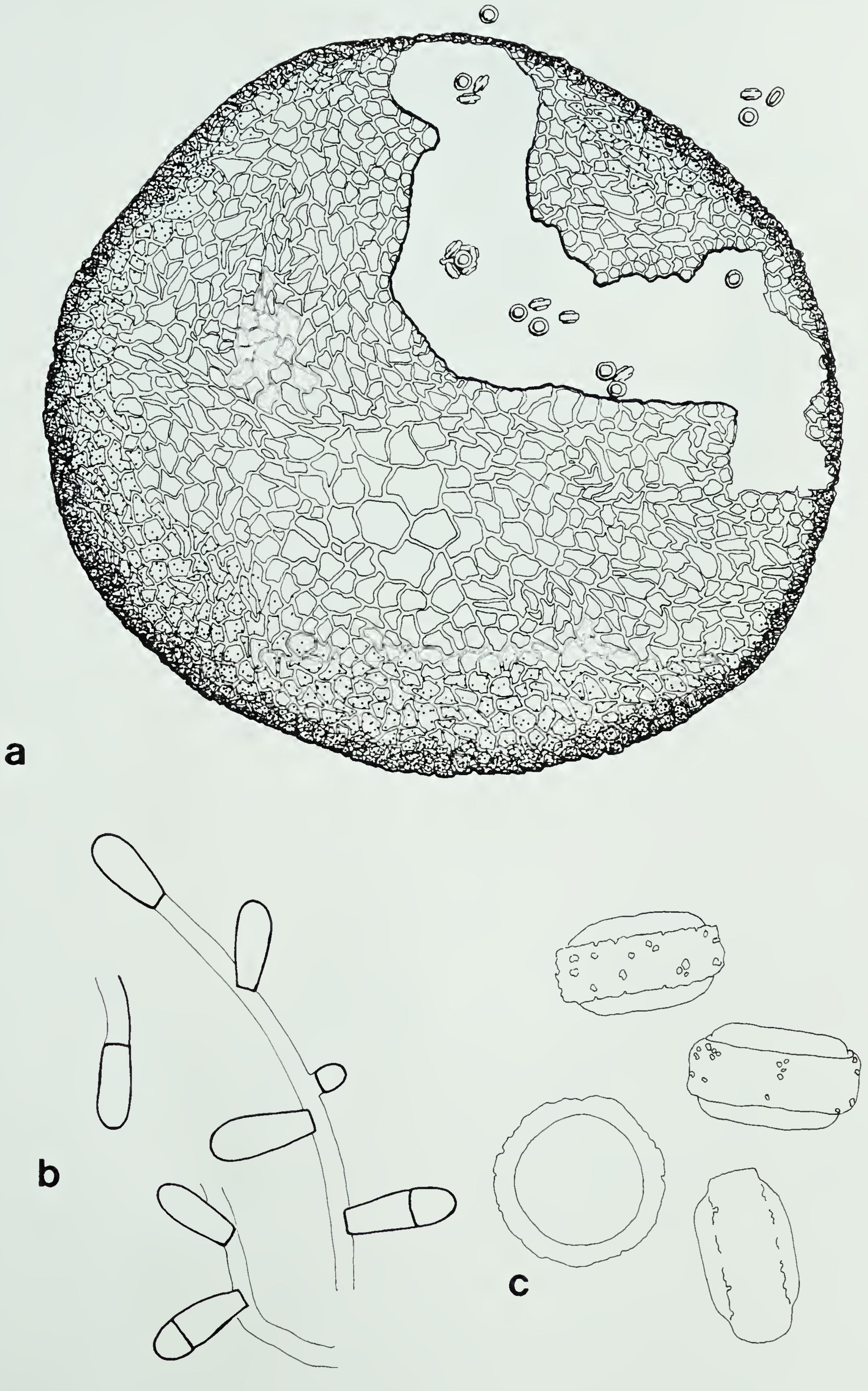

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Figure 7.10. *Keratinophyton terreum* (UAMH 2409).

**a** ±Globose cleistothecial ascoma. X535.

**b** Clavate, slightly roughened, solitary aleurioconidia. X1165.

**c** Ascospores with an asymmetric, broad, irregularly punctate, equatorial rim. X7750.

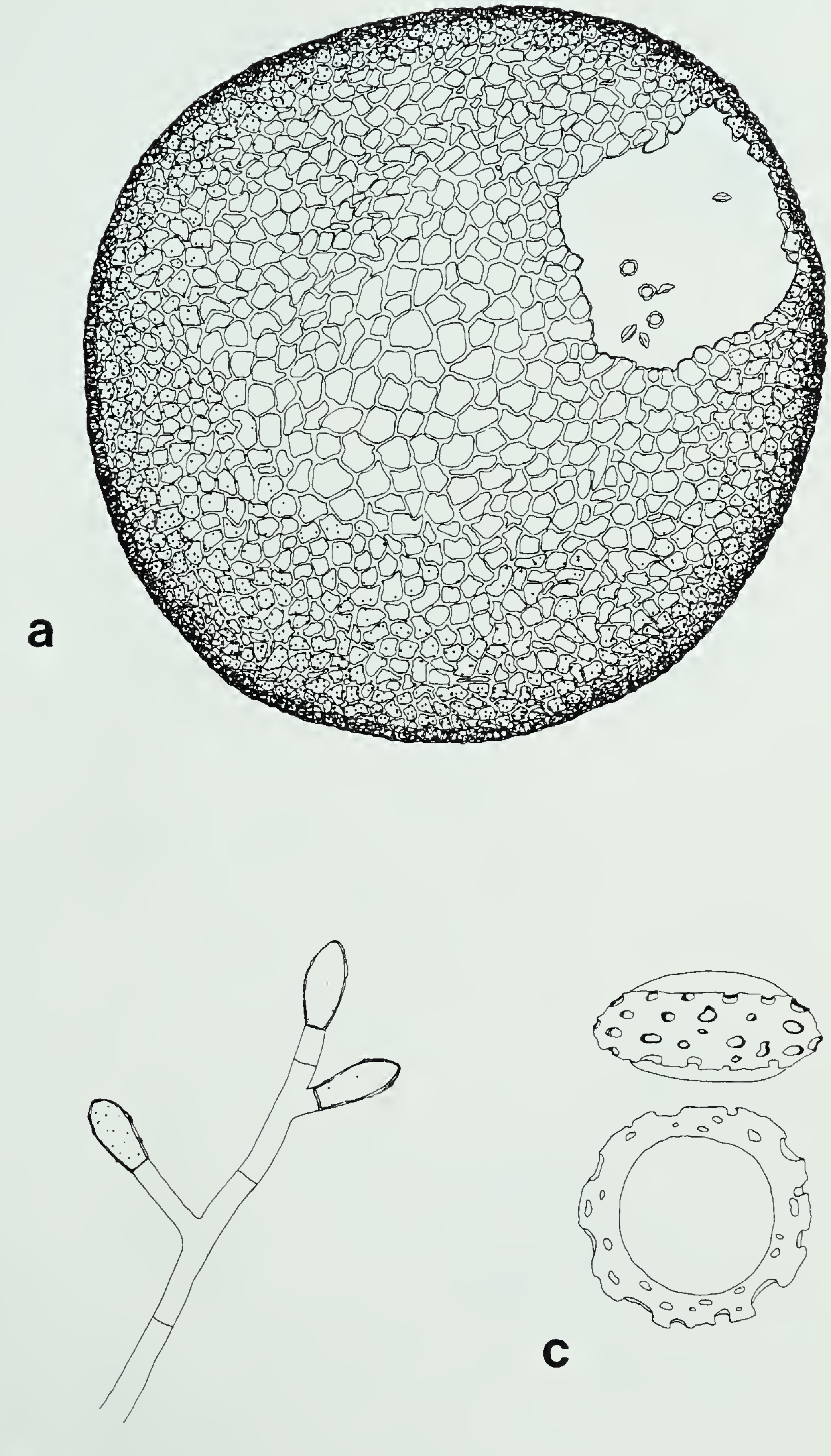
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Figure 7.11. *Nannizziopsis vriesii* (UAMH 3527).

**a** Habit view of two ascomata on roach wing (This drawn from FH, "roach wing," Trinidad). X4.3 approx.

**b** Branched, anastomosed, asperulate hyphae of peridium; hyphae with characteristic constrictions at septa. X1875.

**c** Ascospores with punctate-reticulate walls. X10000.

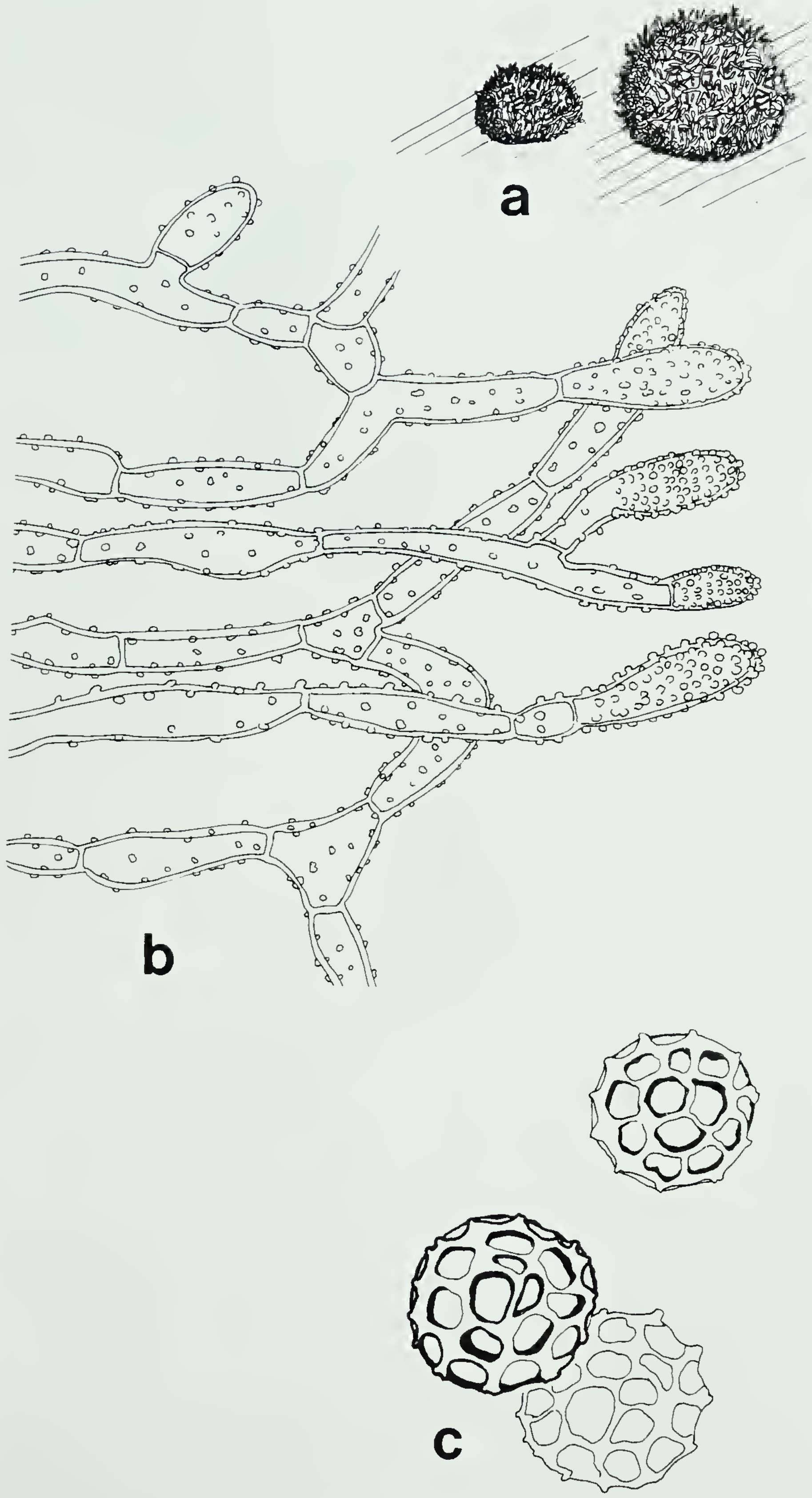
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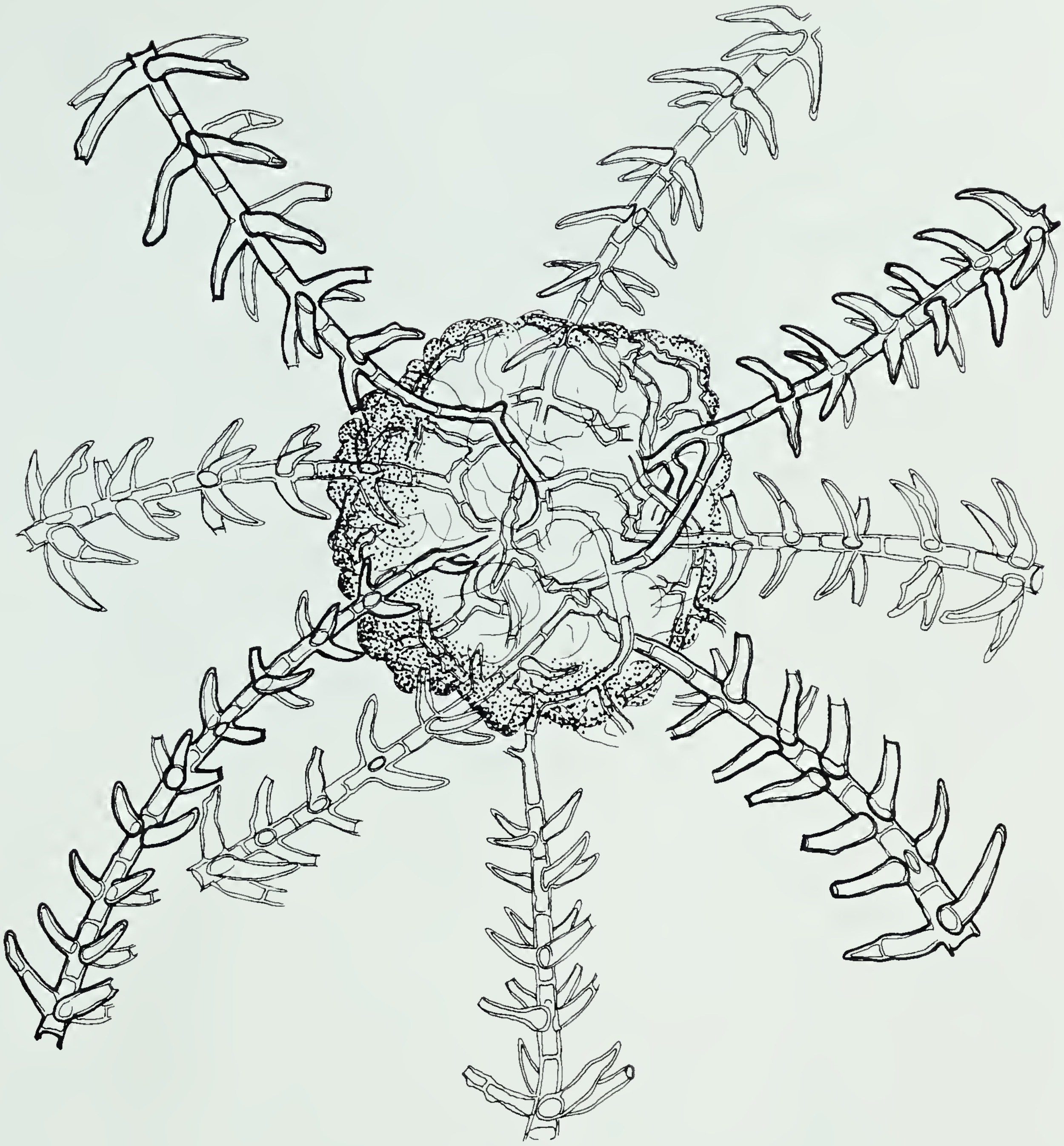
Figure 7.12. *Oncocladium flavum* (UAMH uncatalogued).

a Ascoma-like organization of verticillate appendages. X500.

b *Malbranchea flava* anamorph. X1400.



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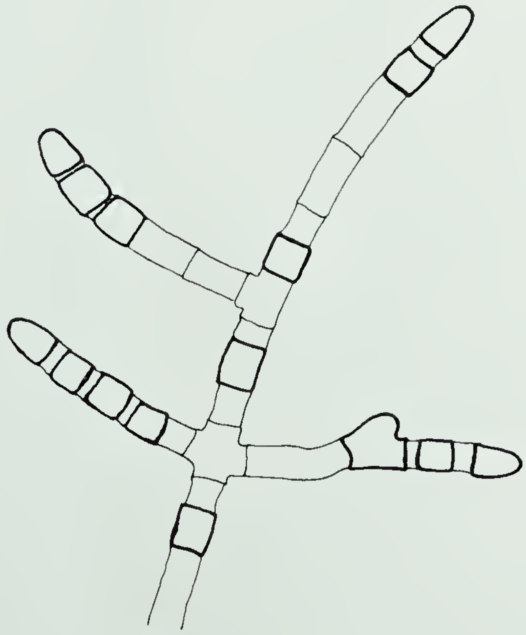

b

Figure 7.13. *Pectinotrichum llanense* (NY O-779).

**a** Elaborately appendaged reticuloperidium showing elongate, tapering appendages and pectinate structures (arrow). X540.

**b** Anamorph of smooth, bluntly pointed aleurioconidia. X2000.

**c** Oblate, thick-walled, punctate ascospores. X10000.

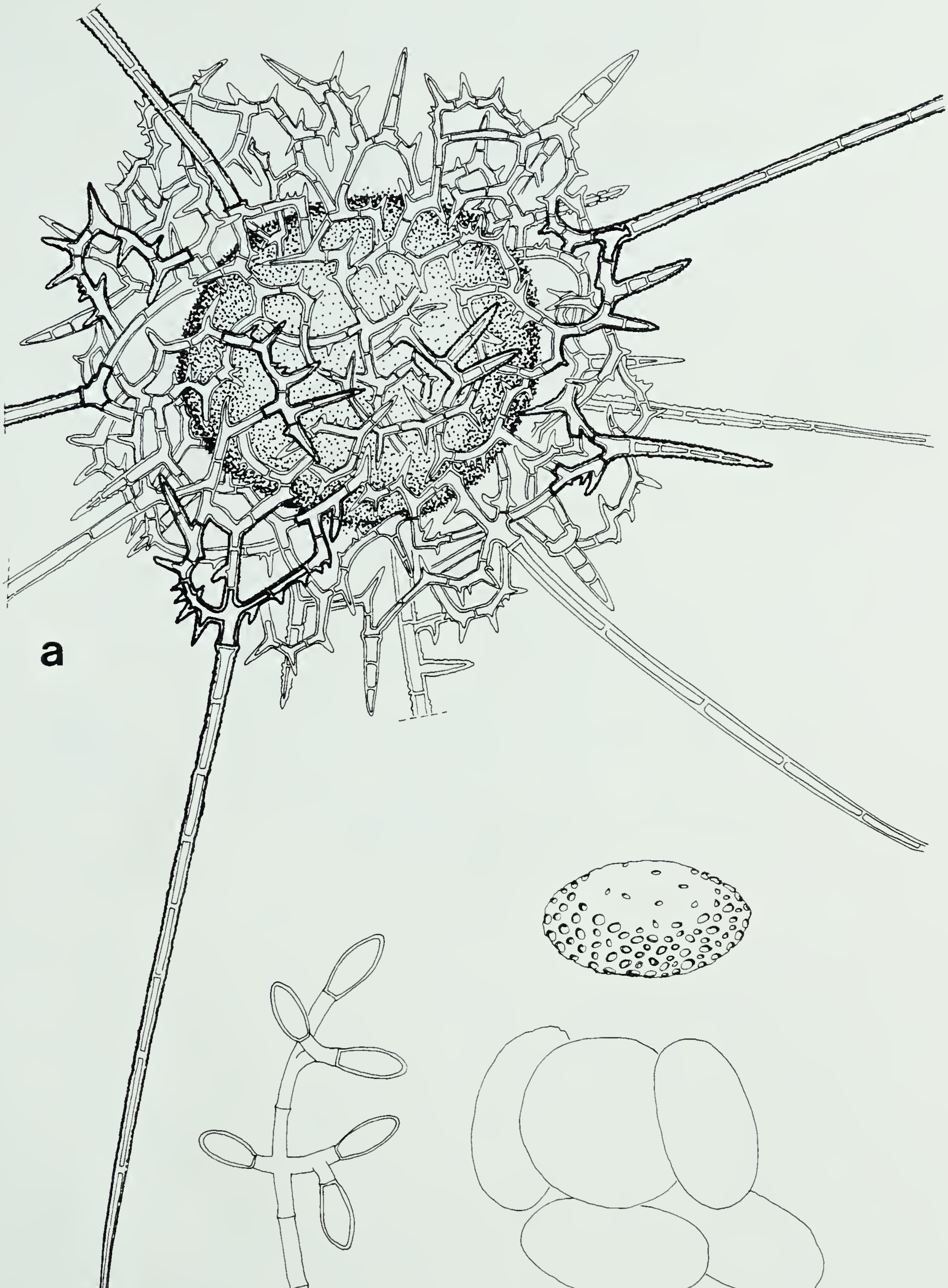
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Figure 7.14. *Shanorella spirotricha* (RSA 156).

**a** Incompositothecium of disarticulated, irregularly thick-walled irregular cells. X1000.

**b** Anamorph of clavate, and oblong conidia. X2500.

**c** Ascospores and conglobate ascal cluster. X2500.

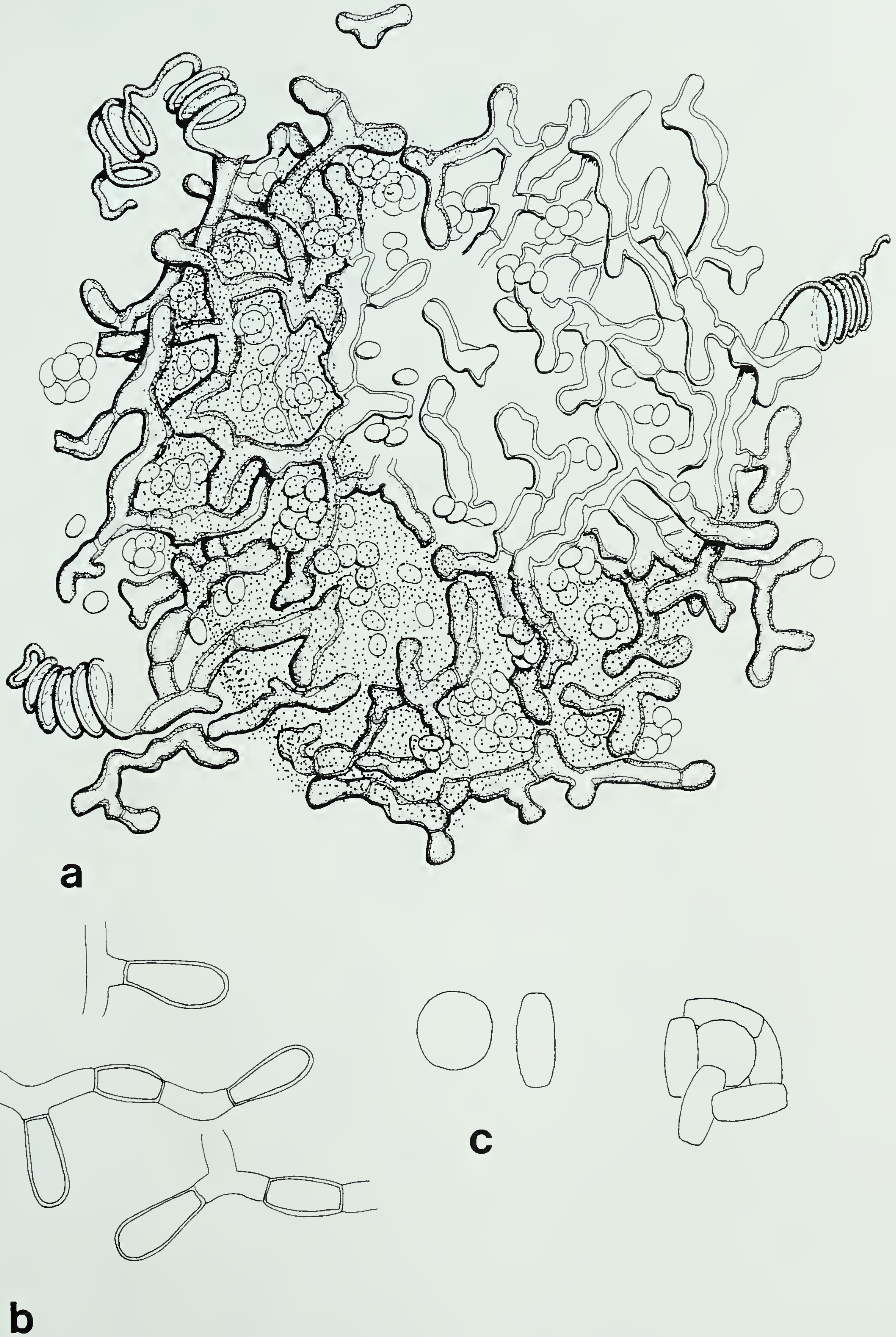
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Figure 7.15. *Uncinocarpus reesii* (UAMH 3882).

a Ascoma showing loose arrangement of appendages and ascospores. X665.

b Anamorph of barrel-shaped, intercalary conidia. X1165.

c Oblate, finely punctate ascospores. X7775.

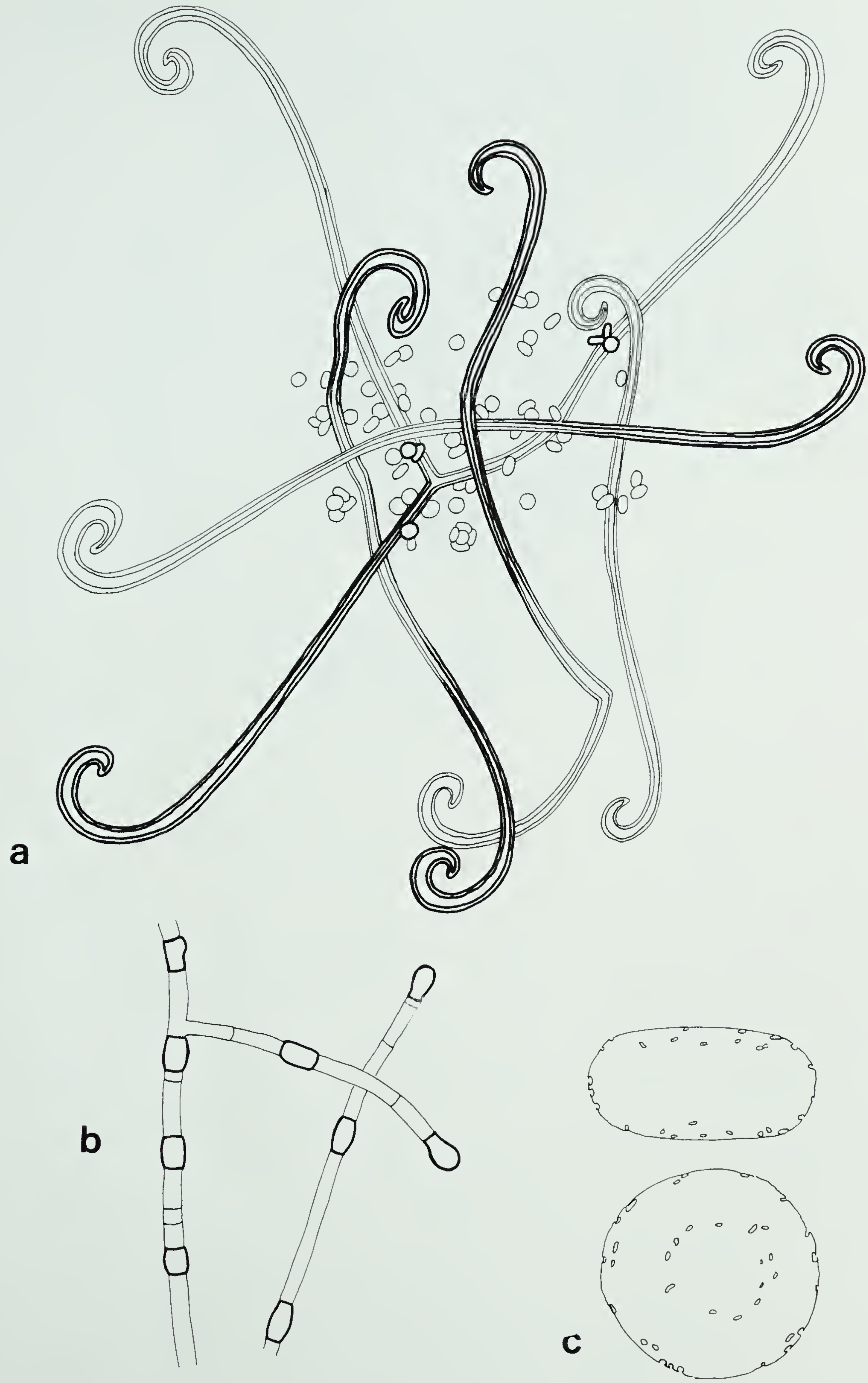
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Figure 7.16. *Uncinocarpus uncinatus* (RSA 56).

**a** Reticulothecium with numerous thick-walled, uncinate appendages. X375.

**b** Roughened terminal and intercalary conidia. X1665.

**c** Oblate ascospores and ascal cluster. X3830.

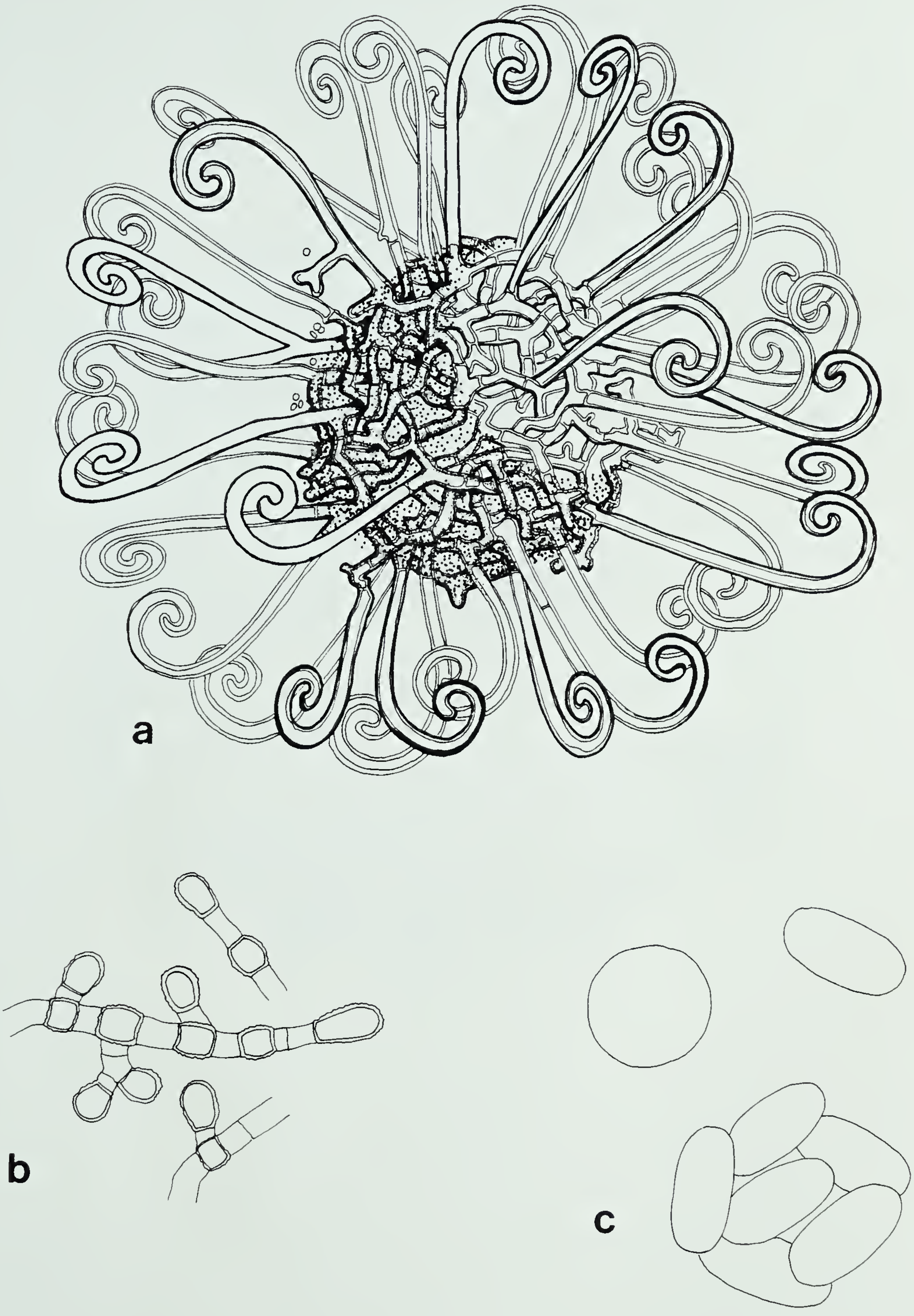
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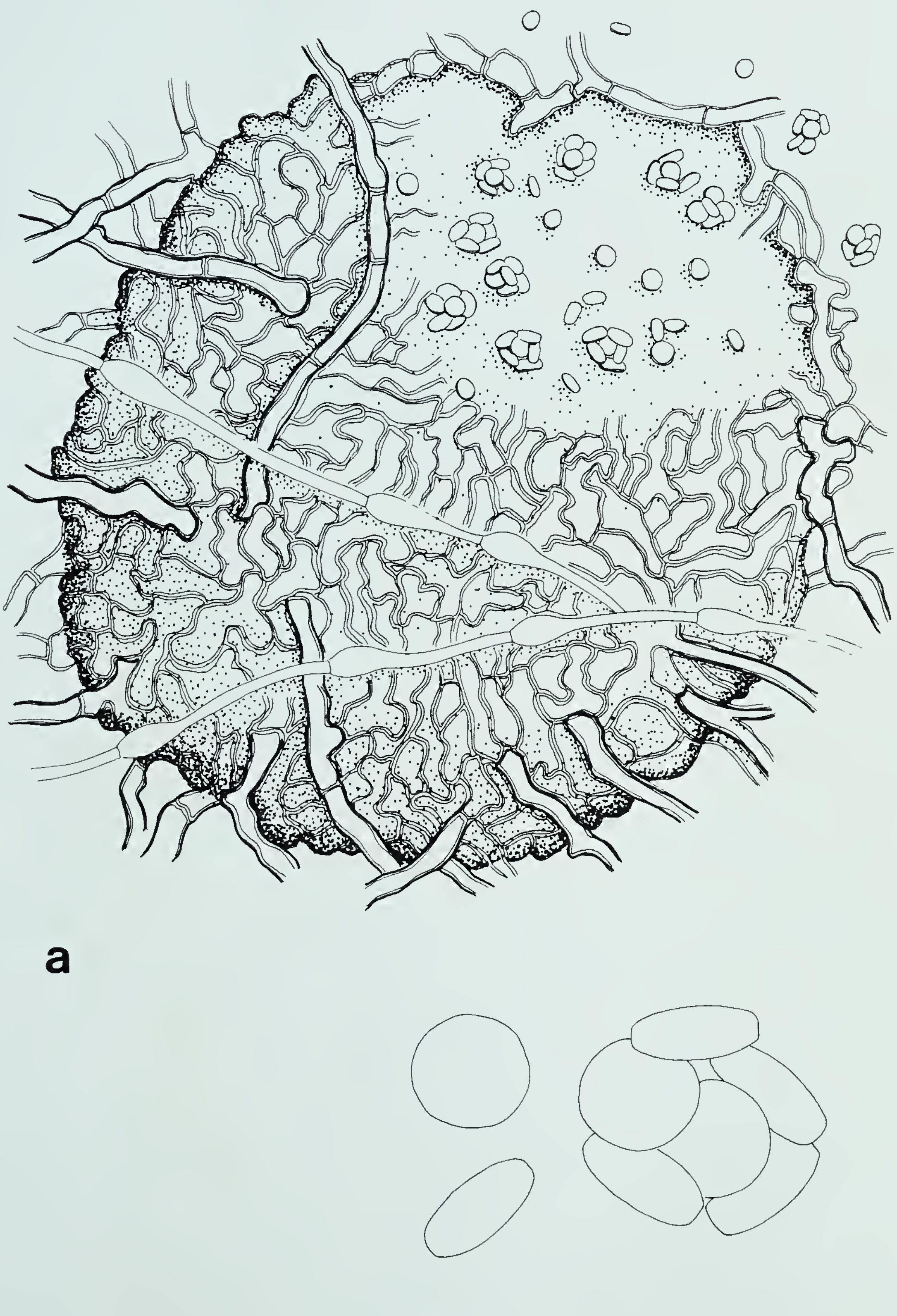
Figure 7.17 *Xynophila mephitalis* (TRTC 42886).

a Individual, naked, membranous ascoma. X1140.

b Oblate ascospores, free and in a conglobate ascal cluster. X5285.



a

b

Plate 7.1.

**a** *Amauroascus mutatus* (UAMH 3563). Spherical, punctate ascospore with "hoodoo-like" pila projecting beyond the finely punctate surface. X10000.

**b** *Amauroascus volatilis-patellis* (UAMH 3406). Spherical ascospore with broad, deep, regularly-shaped pits. Some smaller puncta on outer rim surface. X14250.

**c** *Amauroascus niger* (UAMH 3544). Spherical ascospore with irregular punctum pattern. X17000.

**d** *Amauroascus aureus* (UAMH 3157). Broad, polygonal puncta with regular rims. Pit floors ornamented with smaller pits. X16500.

**e** *Amauroascus albicans* (UAMH 3402). Spherical ascospores with numerous, deep, circular pits. X21000.

**f** *Amauroascus kuehnii* (UAMH 3). Spherical ascospore with deep, round, regular pits. X19000.

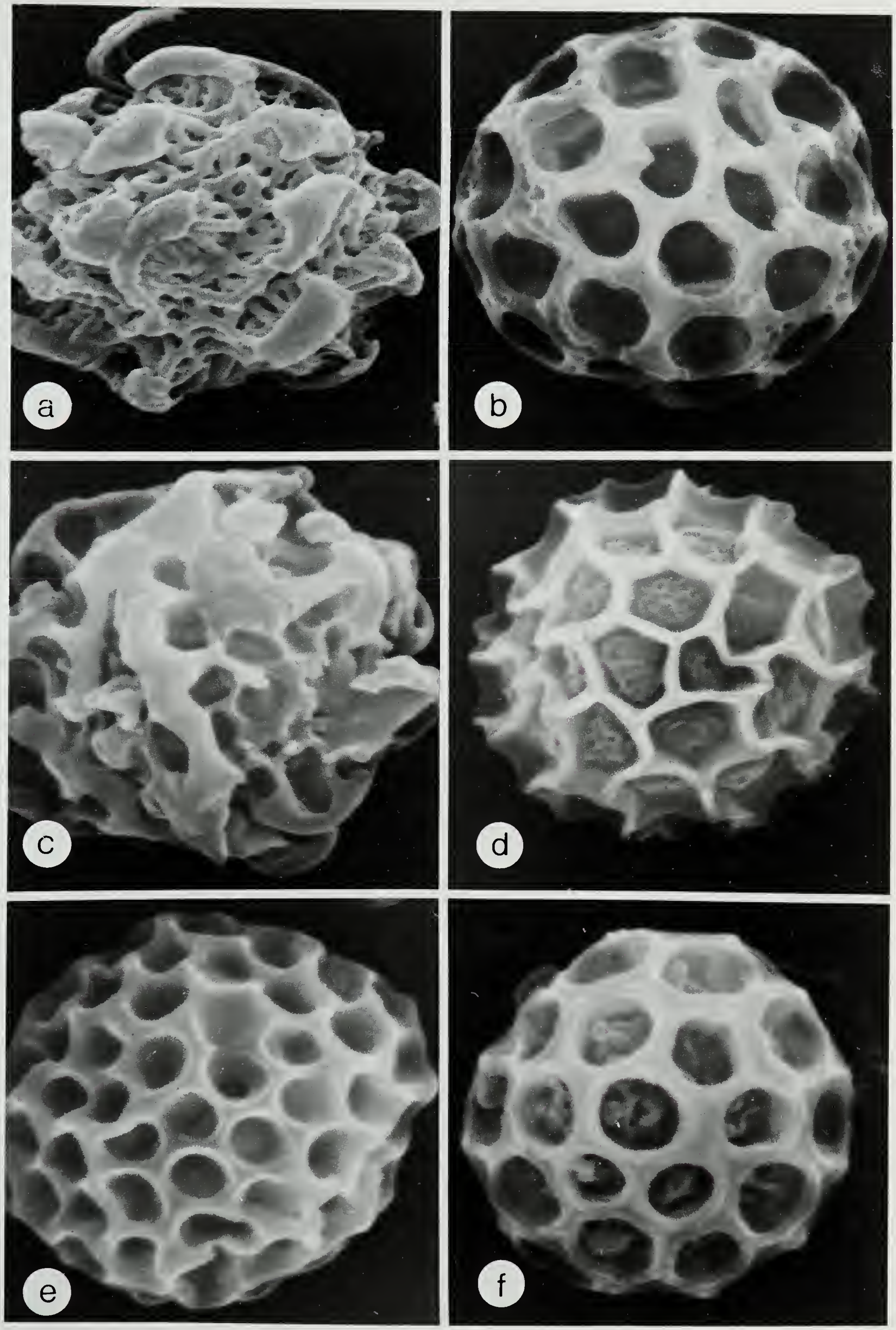

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Plate 7.2.

**a** *Amauroascus pseudoreticulatus* (RSA 1426). Conglomeration of ascospores and thick-walled hyphae which lack recognizable peridial organization. X90.

**b** *Amauroascus pseudoreticulatus* (RSA 1426). Spherical ascospores with broad, polygonal puncta on surface. X1220.

**c** *Amauroascus kuehnii* (RSA 1254). Thick-walled peridial hyphae. X90

**d** *Amauroascus kuehnii* (RSA 1254). Thick-walled hyphae and punctate ascospores. X1570.

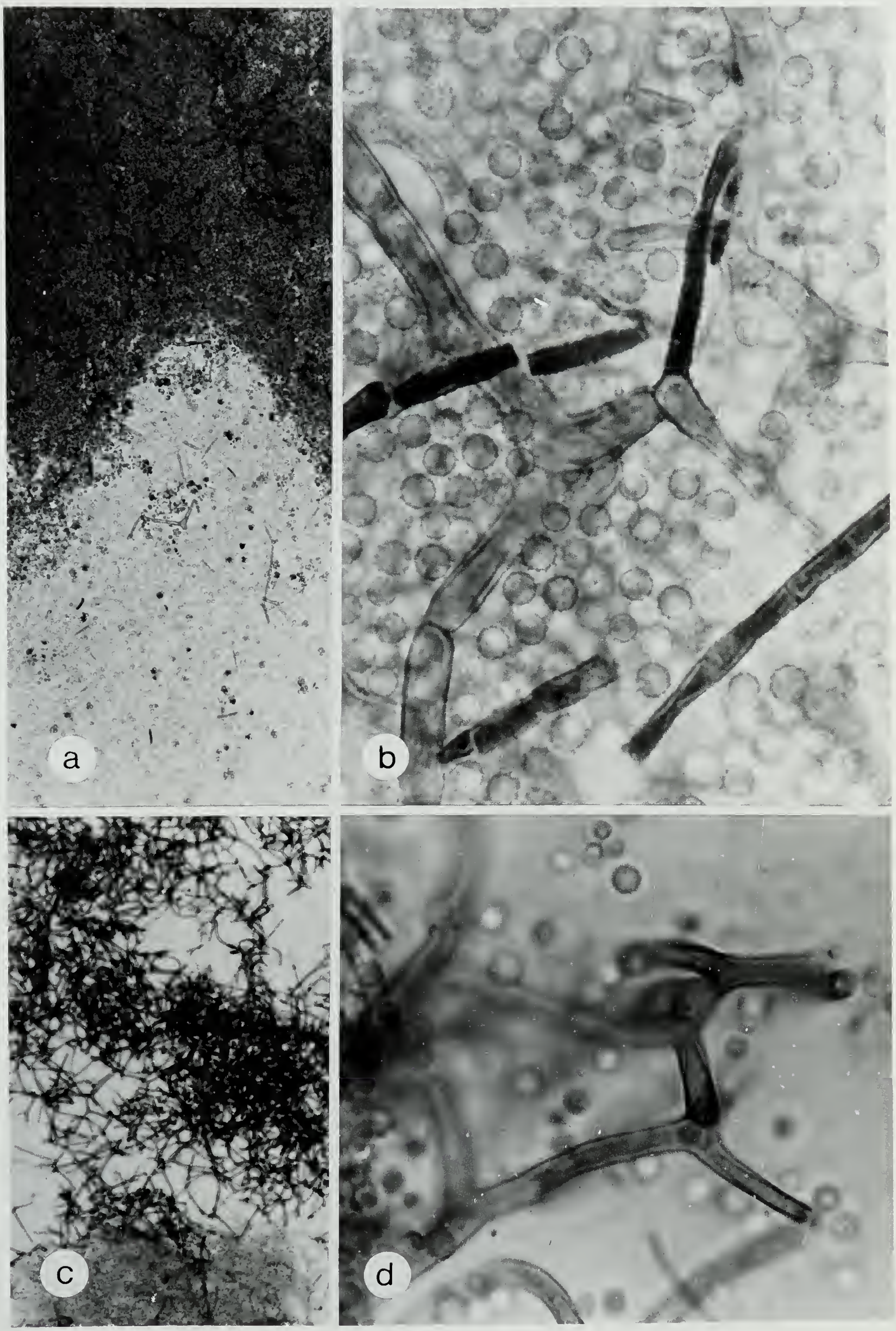
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Plate 7.3.

a *Aphanoascus fulvescens* (UAMH uncatalogued). Habit view of ascoma on natural material (dung). X20.

b *Aphanoascus fulvescens* (UAMH 4603). Punctate, oblate ascospores in ascal clusters within an ascoma . X1450.

c *Aphanoascus fulvescens* (UAMH uncatalogued). Habit view of several ascomata on natural material. X13.

d *Aphanoascus fulvescens* (UAMH 4603). Membranous, pigmented ascoma wall and oblate ascospores. X1540.

e *Aphanoascus fulvescens* (UPS "Feurich"). Squashed ascoma . X165.

f *Aphanoascus fulvescens* (TRTC 32680). Punctate-reticulate ascospores (appearing spiny) individual and in ascus clusters. X1050.

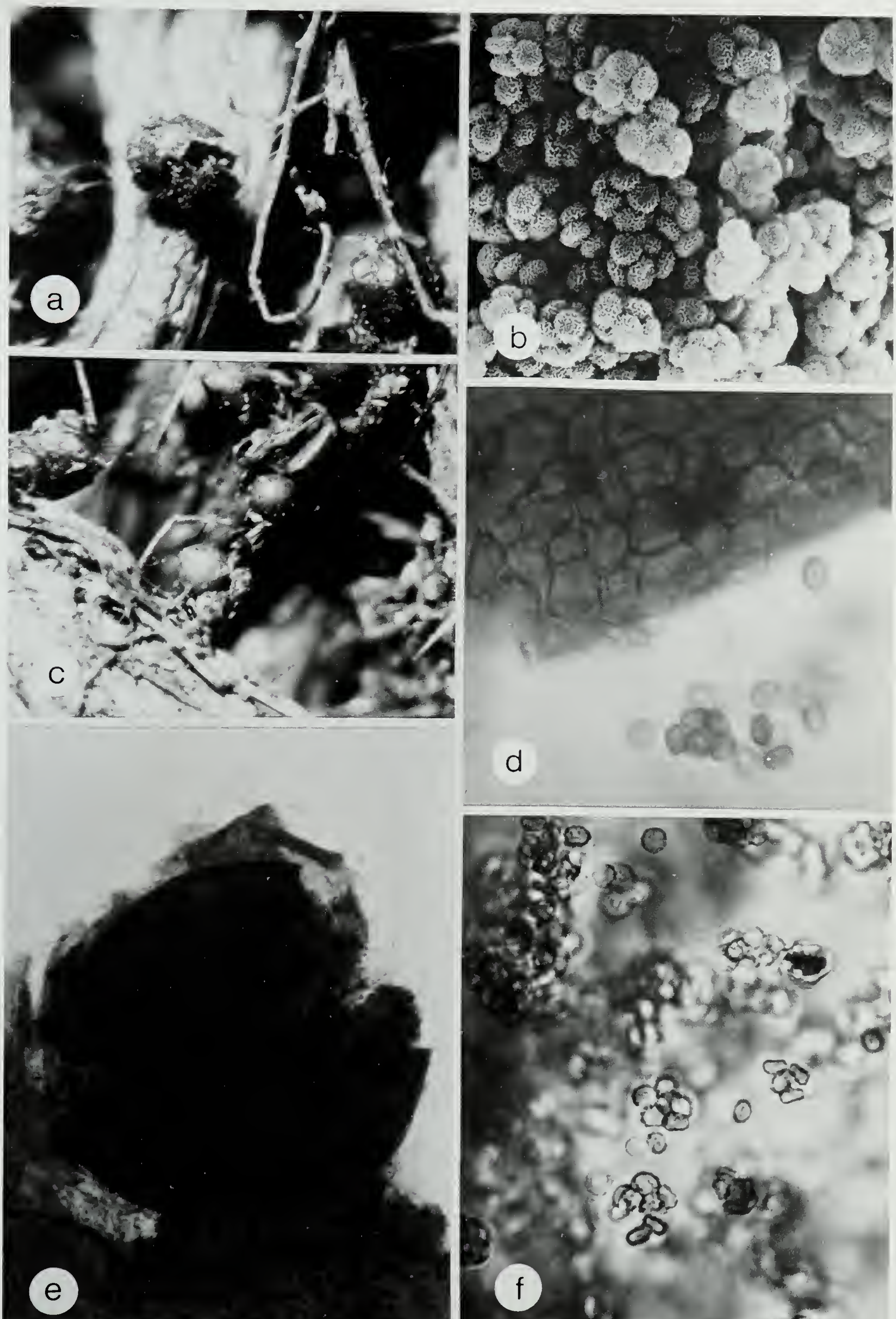
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Plate 7.4.

**a** *Auxarthron californiense* (UAMH 3151). Oblate punctate ascospore. X28500.

**b** *Neogymnomyces demonbreunii* (UAMH 3382). Thick-walled oblate-ovoid ascospore with irregular, elongated pits. X19500.

**c** *Auxarthron californiense* (UAMH 3151). Conglobate cluster of oblate ascospores. X14000.

**d** "*Amauroascus reticulatus*" (UAMH 3560). Sheathed ascospore. X19000.

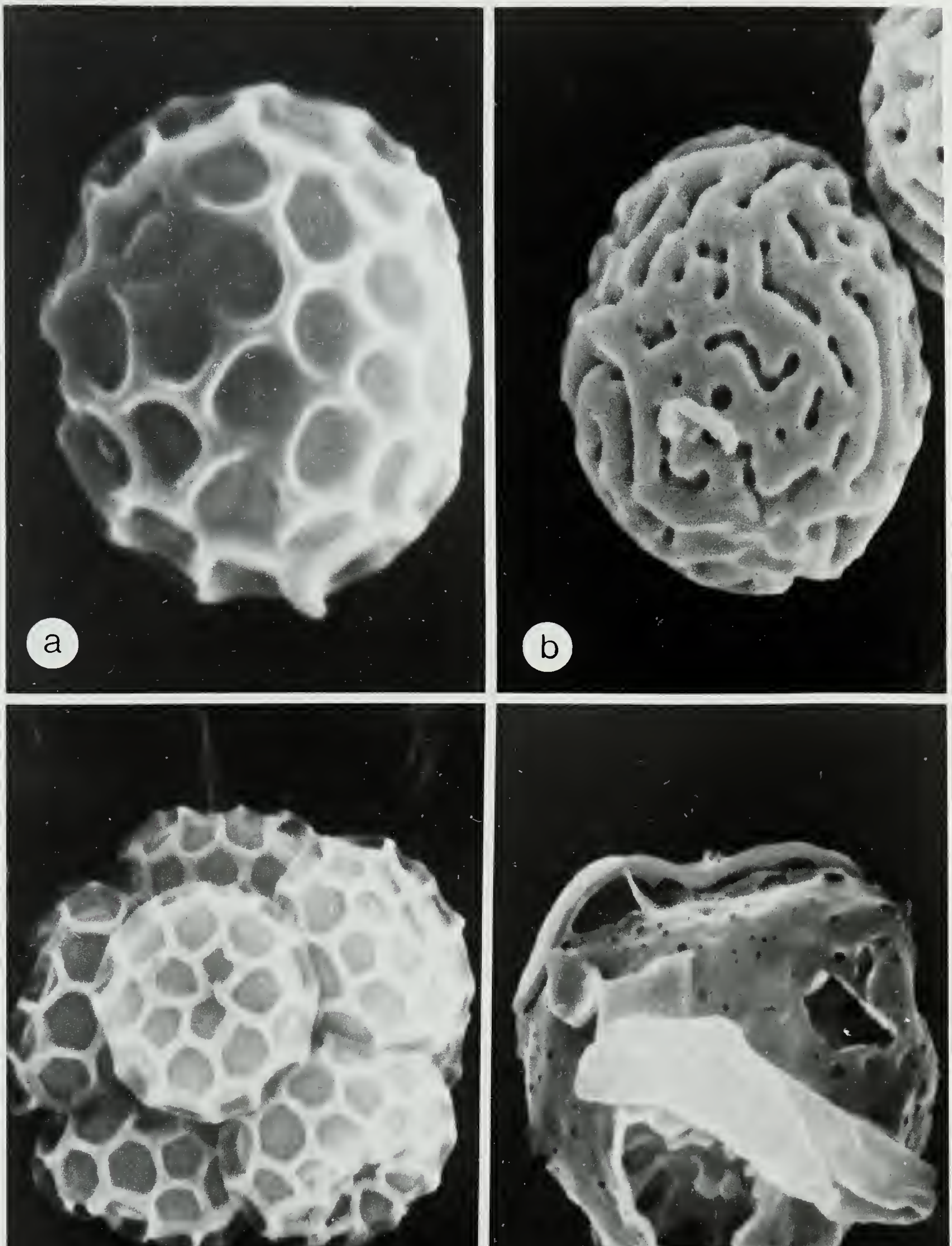
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Plate 7.5.

**a** *Auxarthron californiense* (RSA 1525). Thick-walled, uncinate peridial appendages with enlarged basal septum ("knuckle-joint"). X945.

**b** *Auxarthron reticulatum* (RSA 1528). Ascoma with organized reticuloperidium of thick-walled hyphae. Appendages short and blunt. X335.

**c** *Auxarthron californiense* (RSA 1525). "Y"-shaped configuration of peridial element giving rise to uncinate appendage. X1250.

**d** *Uncinocarpus uncinatus* (FH "hen dung"). Septum (arrow) at base of uncinate appendage. Compare with PL 7.5.c. X1875.

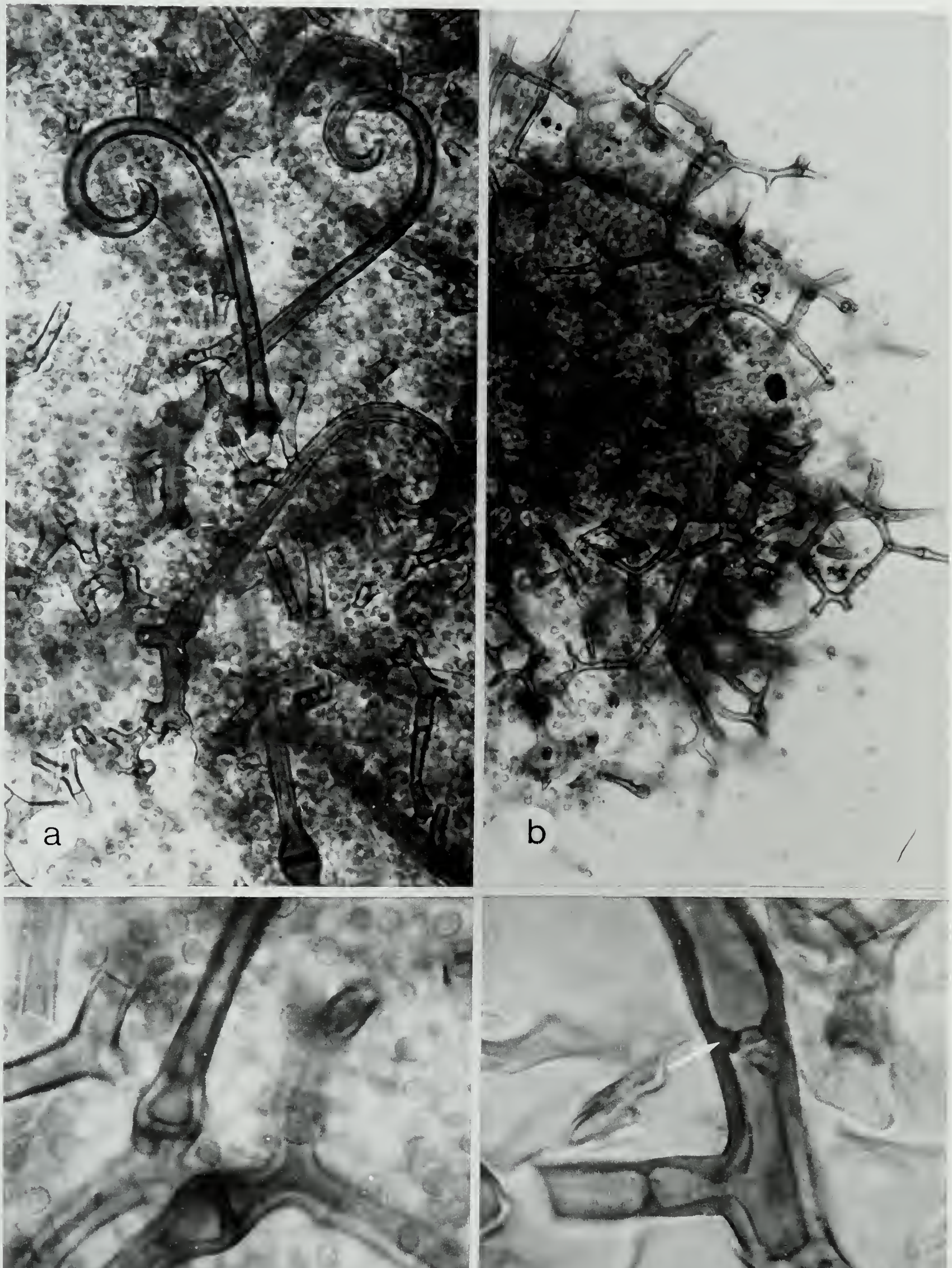
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Plate 7.6.

**a** *Auxarthron compactum* (NY O-573). Reticulothecium composed of short, broad, thick-walled cells. X520.

**b** *Auxarthron pseudauxarthron* (UAMH 3404). Fine asperulations on hypha of reticuloperidium. X22000.

**c** *Auxarthron conjugatum* (UAMH 3874). Coarse asperulations on hyphae of peridium. X6500.

**d** *Auxarthron conjugatum* (NY O-532). Reticulothecium with long appendages. X150.

**e** *Auxarthron pseudauxarthron* (UAMH 3404). Lax, open reticuloperidium of slender, elongated cells. X250.

**f** *Auxarthron zuffianum* (NY O-514). Reticulothecium with numerous short, needle-like appendages. X150.

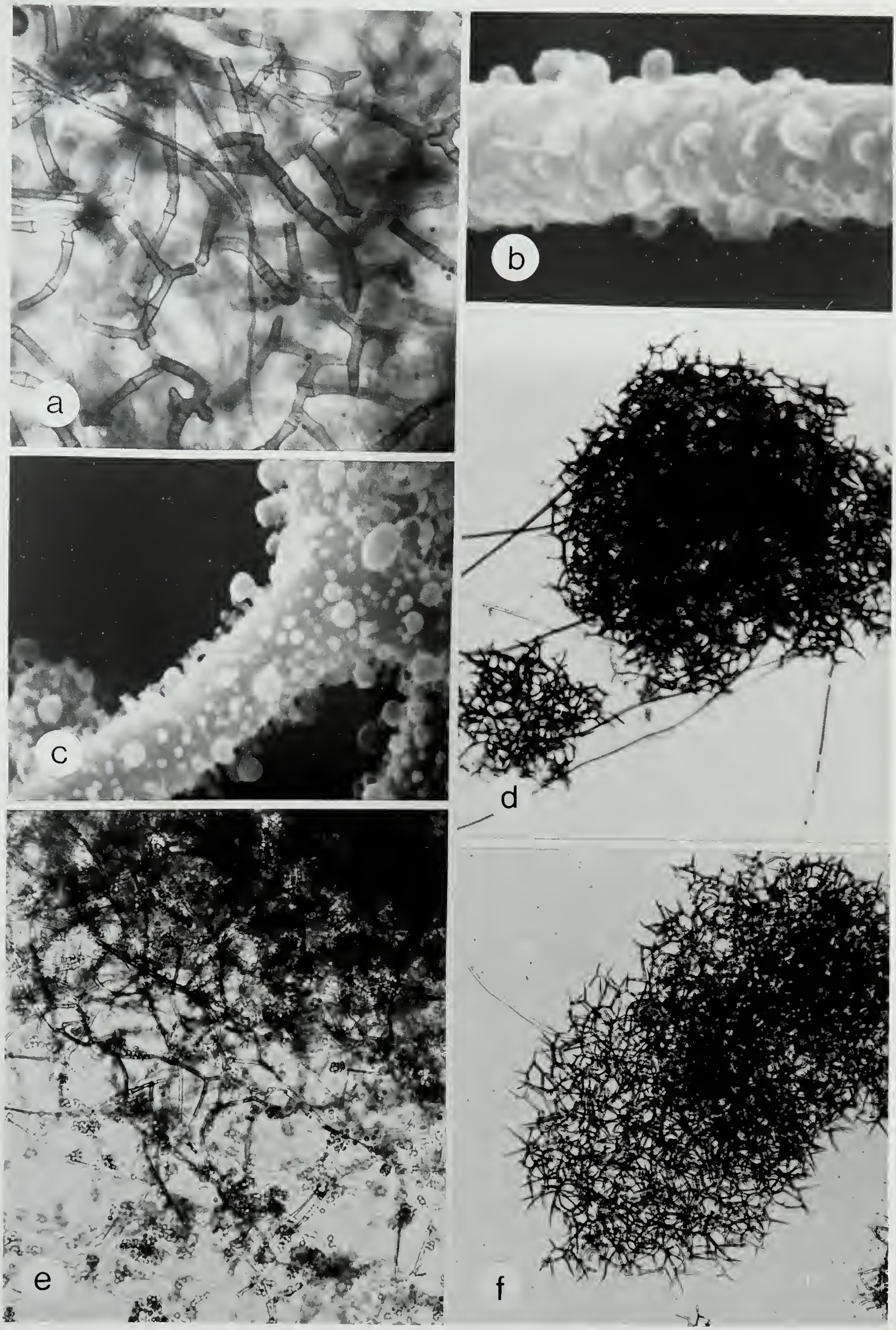
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Plate 7.7.

**a** *Auxarthron conjugatum* (UAMH 3874, type strain of *Macronodus bifurcatus*). Pitted ascospore and coarsely asperulate cell of peridium (cf. PL 7.7.c). X13500.

**b** *Auxarthron brunneum* (UAMH 3118). Ascospore with rounded, shallow puncta and wide punctum ridges. X23000.

**c** *Auxarthron conjugatum* (UAMH 3118, type strain). Cluster of oblate, reticulate ascospores. X14000.

**d** *Auxarthron reticulatum* (UAMH, 1877). Oblate ascospore with coarse, rounded, polygonal pits. X28000.

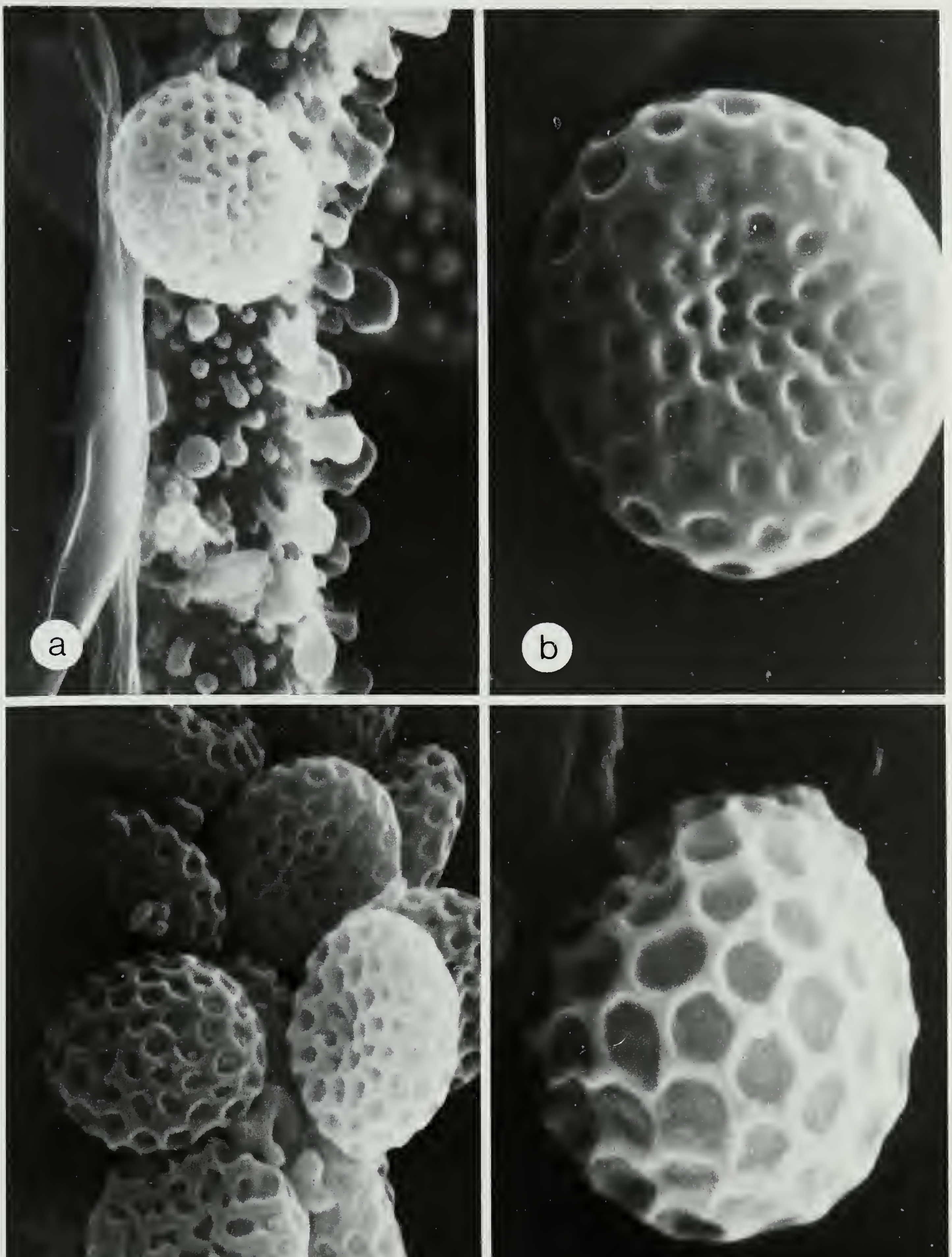
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Plate 7.8.

**a** *Aphanoascus canadensis* (UAMH 4574). Surface appearance of membranous peridium. X1666.

**b** *Aphanoascus canadensis* (UAMH 4574). Globose asci and individual, thick-walled, oblate ascospores from ruptured cleistoperidium. X1375.

**c** *Auxarthron* sp. RC1 (UAMH uncatalogued). Reticulothecium with long, curved, needle-like, septate appendages. X270.

**d** *Auxarthron species RC1* (UAMH uncatalogued). Septate, needle-like appendages paling in color toward apices. X2000.

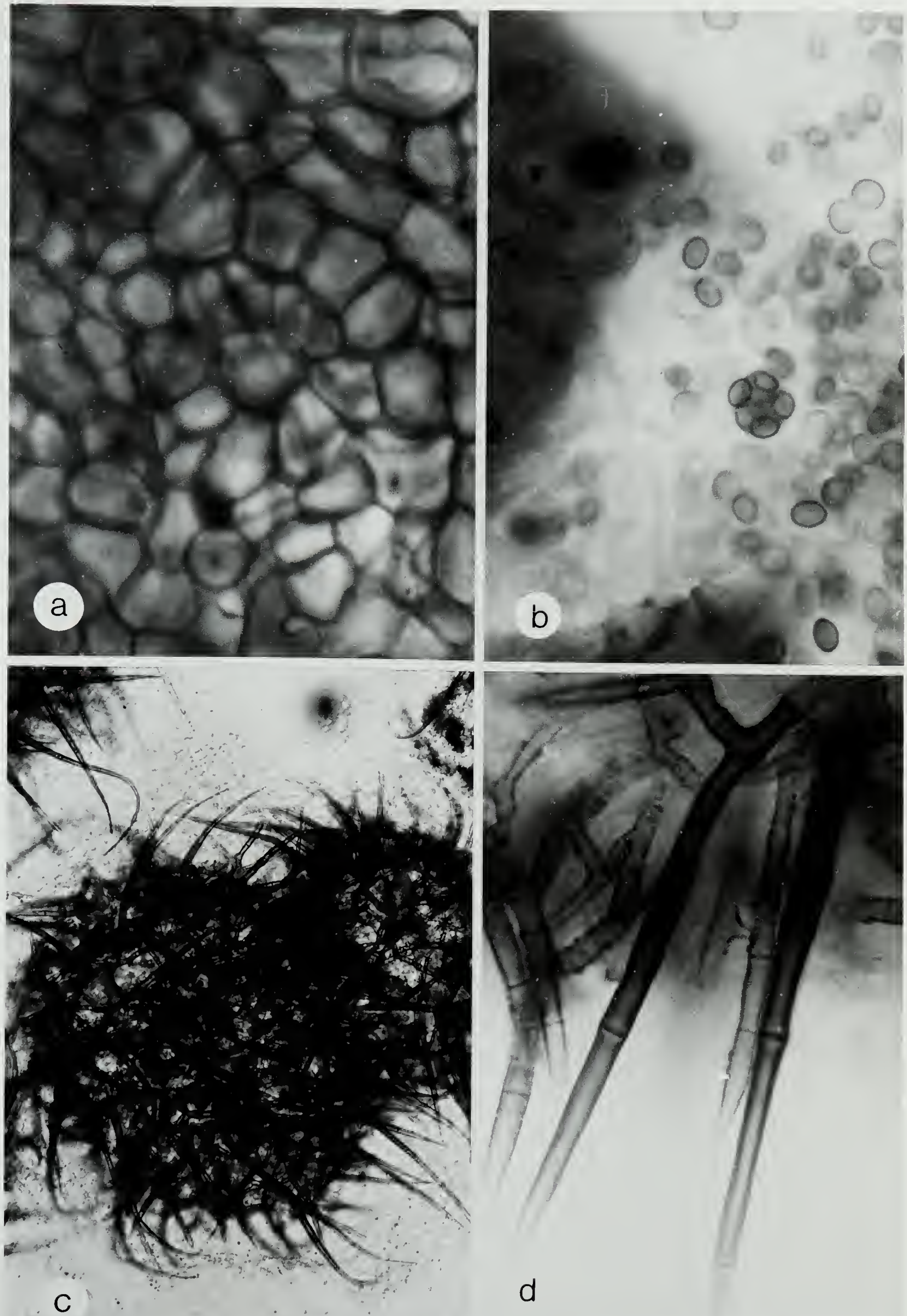
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Plate 7.9.

**a** *Xynophila mephitalis* (TRTC 42886). Oblate ascospore with numerous deep, irregular pits. X15000.

**b** *Pectinotrichum llanense* (UAMH 3400). Oblate ascospore with regular puncta on margin; polar area nearly smooth. X22000.

**c** *Auxarthron pseudauxarthron* (UAMH 3404). Spherical ascospore with numerous regular circular pits. X25000.

**d** *Auxarthron compactum* (UAMH 3153). Oblate ascospore with large irregular, rounded pits. X28000

**e** *Auxarthron conjugatum* (UAMH 3156). Oblate ascospore in polar view. Pit rims thick; puncta ±round to slightly polygonal. X25000.

**f** *Auxarthron reticulatum* (UAMH 1659). Oblate ascospore with regular, rounded pits. X28000.

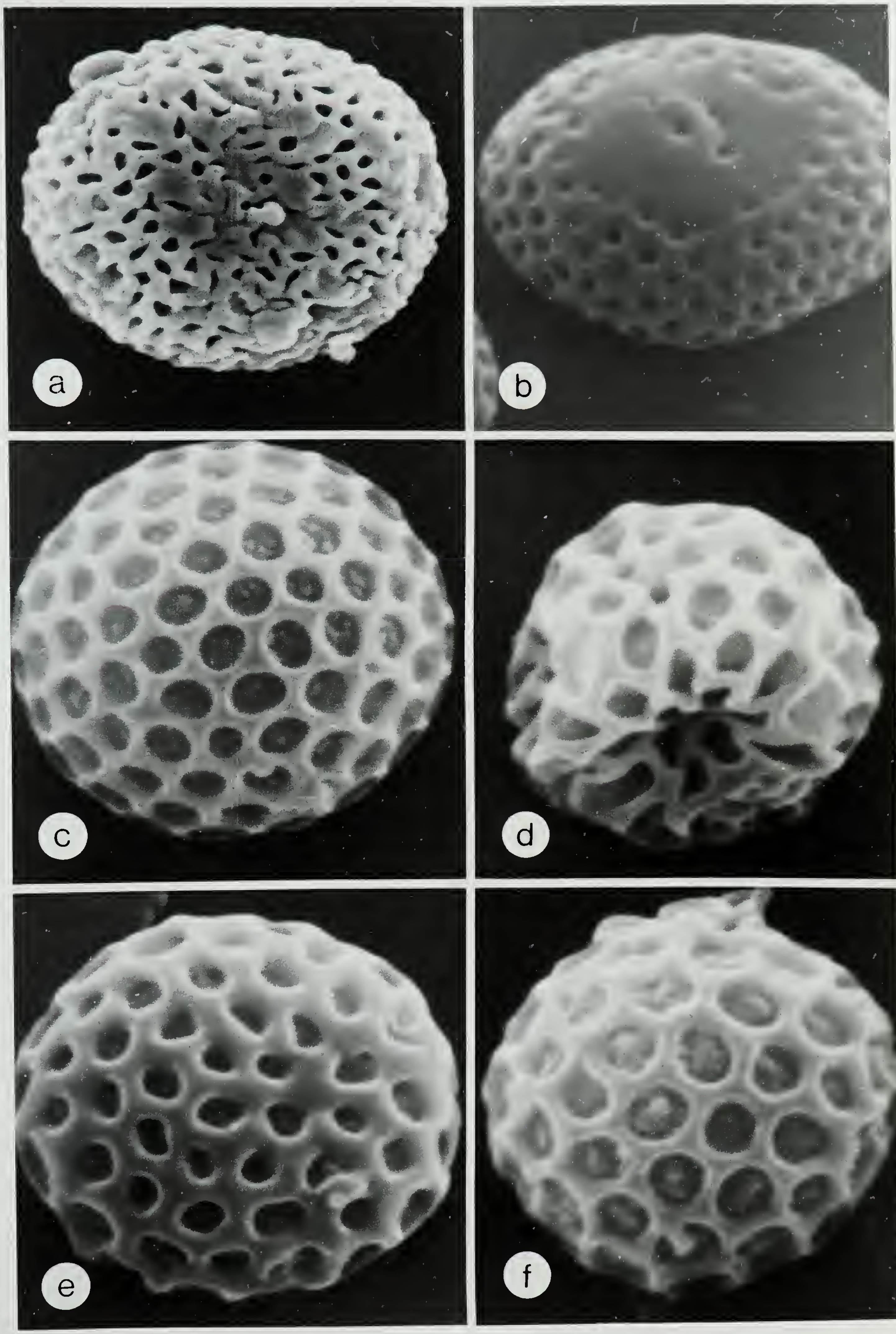
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Plate 7.10.(Phase contrast microphotographs).

**a** *Auxarthron californiense* (UAMH, 1889). Anamorph of alternate, intercalary and terminal conidia. X830.

**b** *Auxarthron conjugatum* (UAMH 3156). Anamorph of broad, intercalary conidia on main hypha; side branches sinuate, with smaller intercalary conidia. X830.

**c** *Auxarthron zuffianum* (UAMH 4484). Swollen, alternate, intercalary arthroconidia. X830.

**d** *Auxarthron umbrinum* (UAMH, 1875). Slender intercalary conidia in long chains. X830.

**e** *Auxarthron reticulatum* (UAMH 1585). Broad, barrel-shaped or squarrose, alternate, arthroconidia in chains. X830.

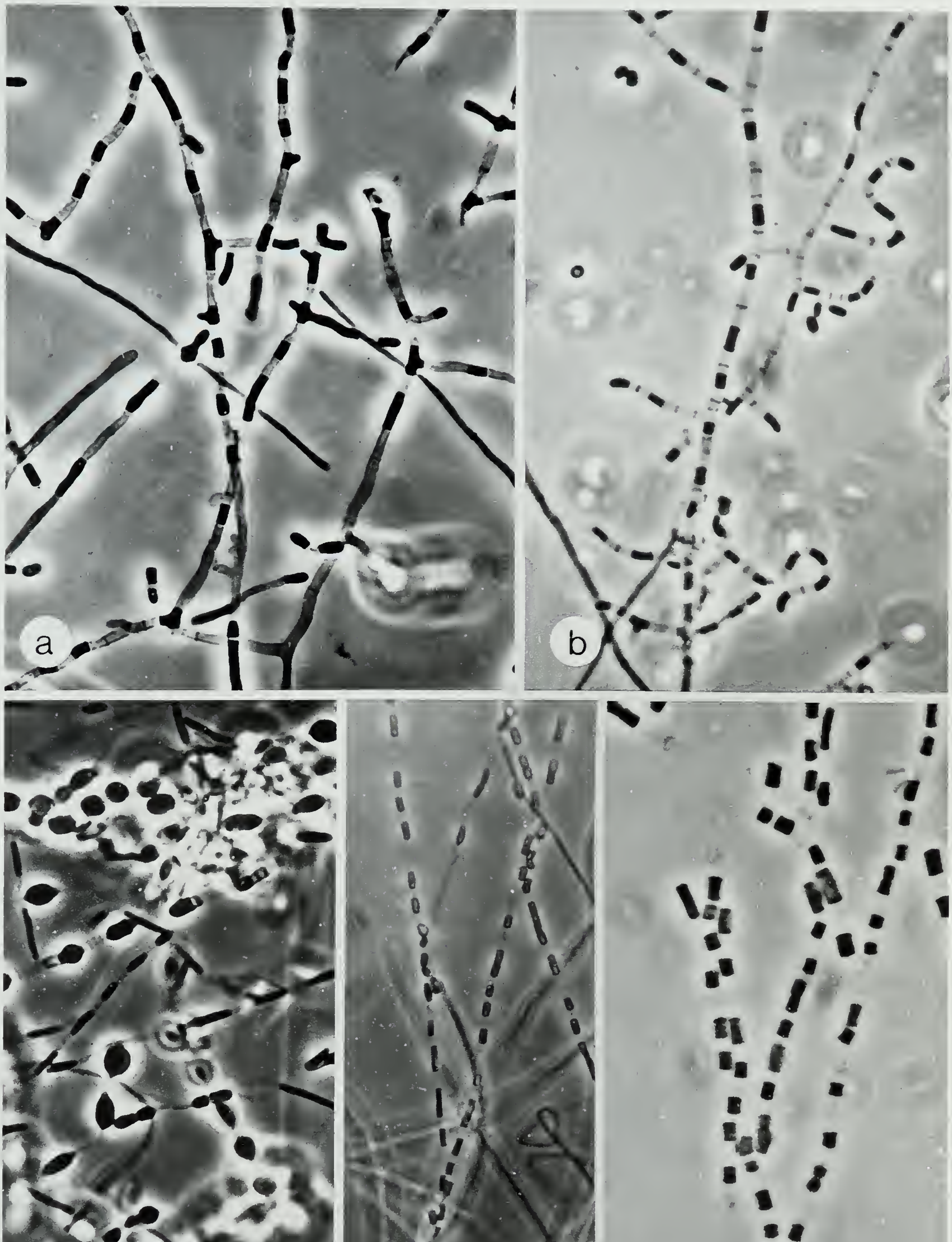
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Plate 7.11.(a,c and d are phase contrast microphotographs).

**a** *Nannizziopsis vriesii* (UAMH 3598). Asperulate peridial elements at periphery of ascoma. Hyphae constricted at septa. X830.

**b** *Nannizziopsis vriesii* (FH "Trinidad"). Characteristic hyphal branching pattern of peridial hyphae and globose, minutely roughened ascospores. X1200.

**c** *Neogymnomyces demonbreunii* (UAMH 3382). Dichotomously branched peridial hyphae. X830.

**d** *Neogymnomyces demonbreunii* (UAMH 3382). Intercalary and terminal conidia often swelling on one side. X830.

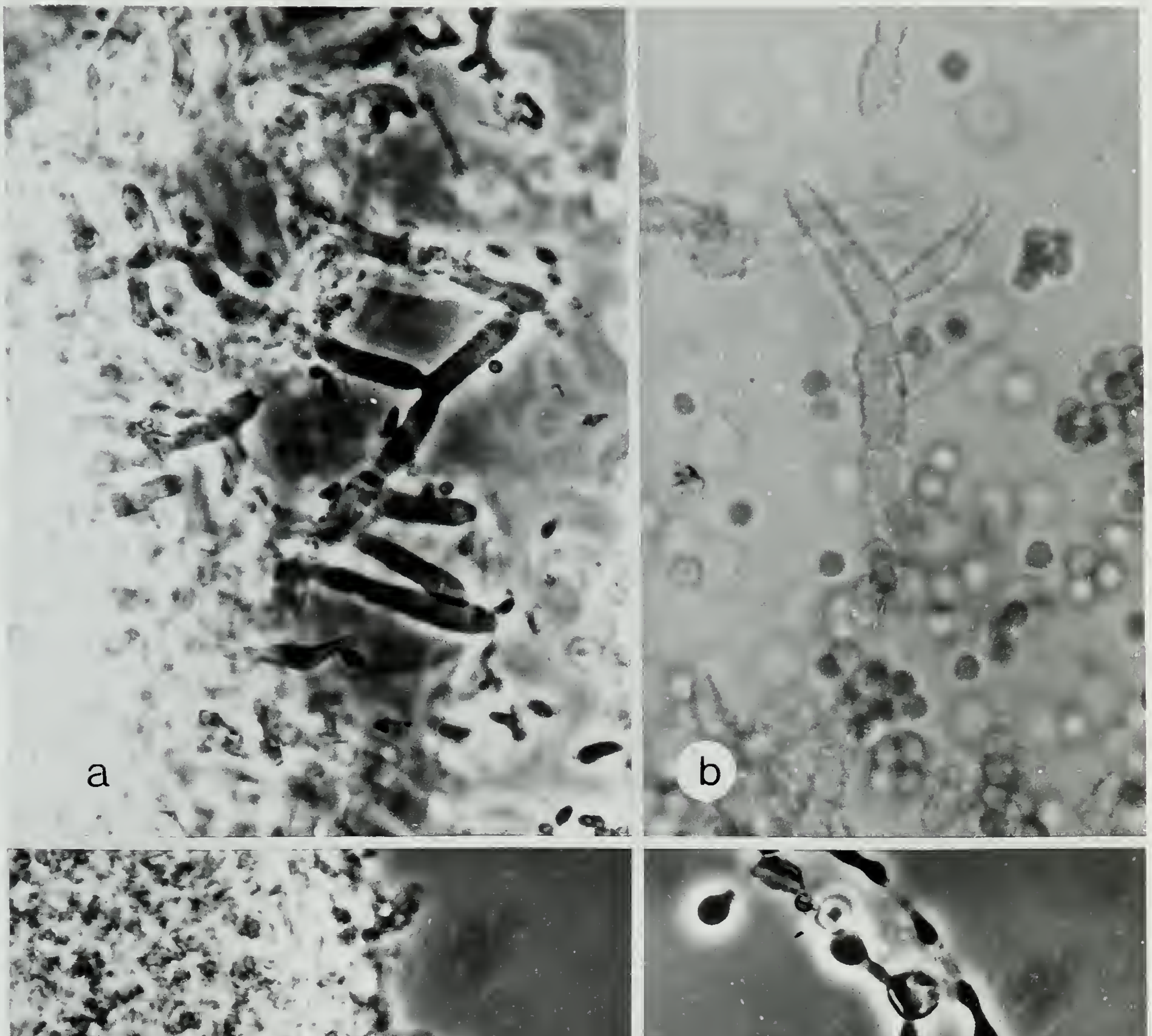
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Plate 7.12.

**a** *Oncocladium flavum* (UAMH 4804). Ascoma-like assemblage of *Oncocladium flavum* (arrows) and its synanamorph *Malbranchea flava*. X110.

**b** *Malbranchea flava* (UAMH 4806). Intercalary and terminal conidia. X770.(Phase contrast microphotographs).

**c** *Oncocladium flavum* (UAMH uncatalogued). Thick-walled *Oncocladium flavum* appendages with verticils of reflexed appendages. X680.

**d** *Onygena equina* (DAOM 124593). Irregular arthroconidia of *Sporendonema* state. X500.

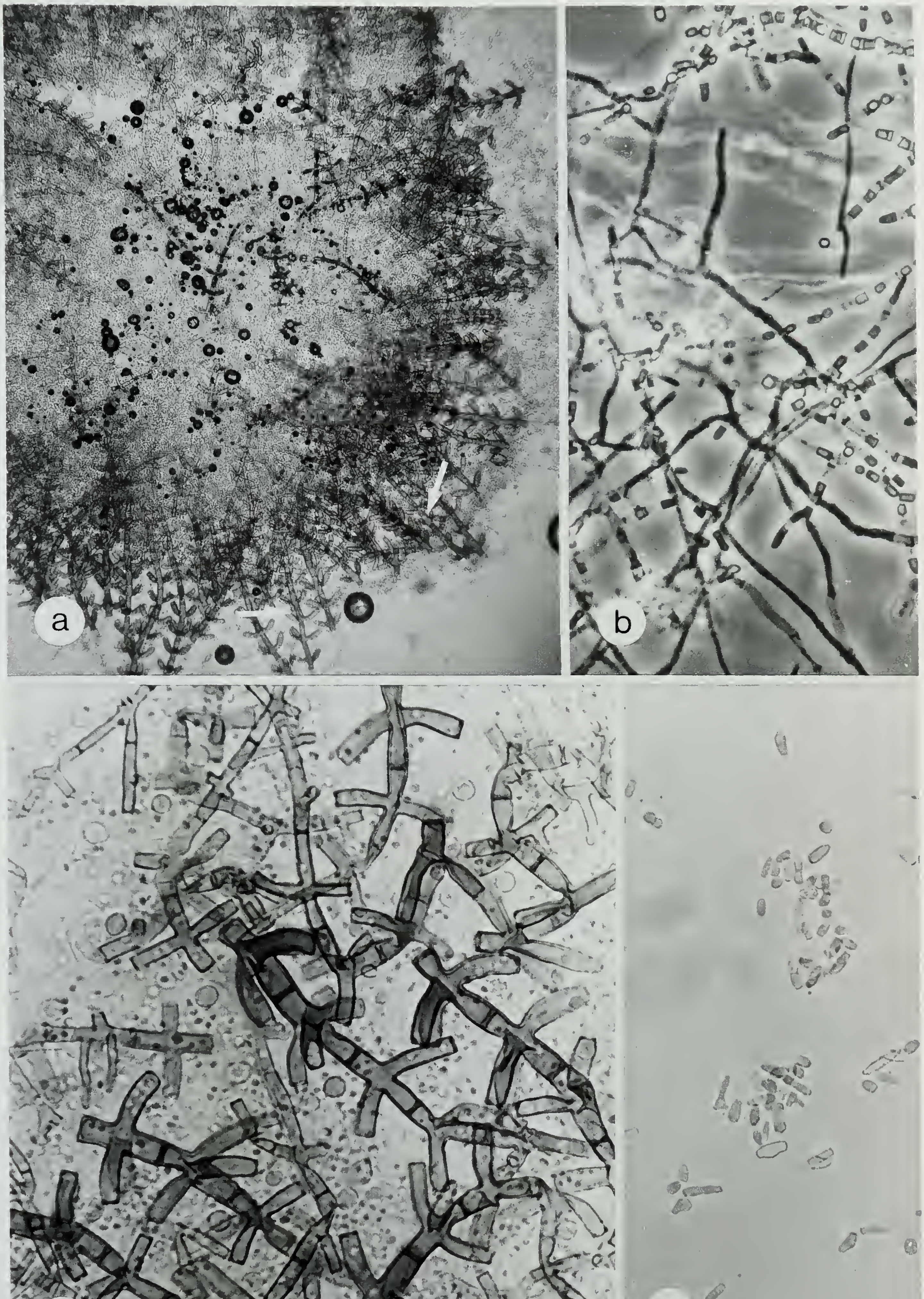

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Plate 7.13

**a** *Onygena equina* (FH Thaxter 1026). Atypical fruit body with a large, irregularly lobed head. X7.

**b** *Onygena equina* (BR Roumeguere 307). Fruit bodies on woollen fabric. X2.

**c** *Onygena equina* (FH Thaxter 1026). Rugulose outer covering ruptured to expose ascospores in head. X8.

**d** *Onygena caprina* (PAV 246). Ruptured fruit body. X30.

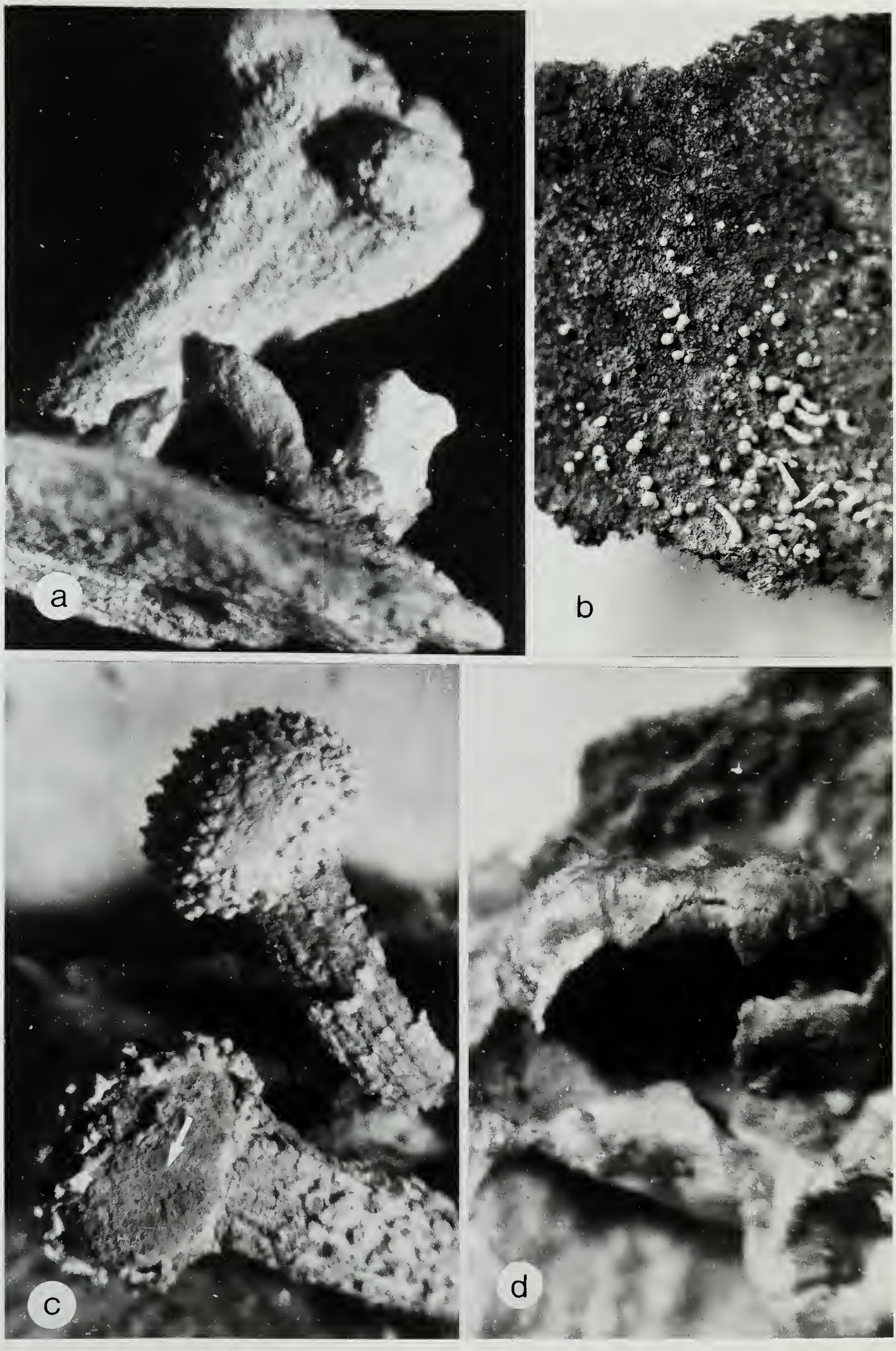

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Plate 7.14.

**a** *Onygena caprina* (BR Roumeguere 307). Irregularly knobbed, ±oblate ascospore with thick, irregular equatorial band. X12500.

**b** *Onygena caprina* (BR Roumeguere 307). Ascal cluster. X1620.

**c** *Onygena caprina* (BR Roumeguere 307). Individual ascospores with irregular equatorial bands. X1300.

**d** *Onygena equina* (MICH "Smith"). Broad, allantoid, apparently smooth ascospore. X1180.

**e** *Onygena corvina* (BR "Belgium 604"). Slender, allantoid, ascospores, each having two prominent guttules. X460.

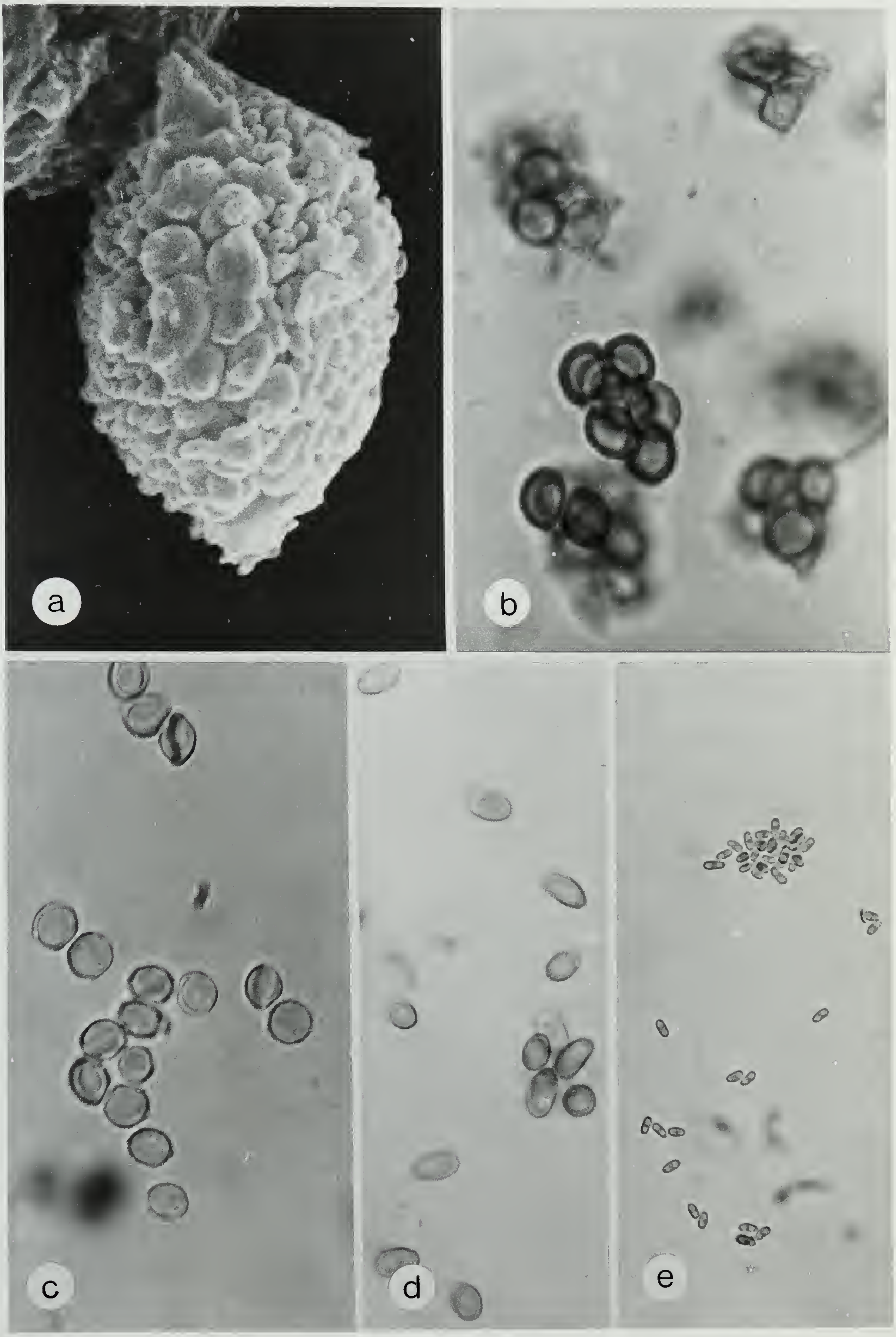
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Plate 7.15.

**a** *Renispora flavissima* (UAMH 4205). Thick-walled, regularly punctate ascospore. Pit rims smooth, round and regular. X25000.

**b** *Onygena corvina* (BR Belgium 604). Thick-walled, allantoid, regularly punctate ascospores. Punctae rounded to irregular. X11500.

**c** *Onygena equina* (MICH "Smith"). Thick-walled, irregularly punctate ascospore. Punctae rounded to irregular. X12500.

**d** *Keratinophyton durum* (UAMH 3671). Thick-walled, oblate ascospore with thick, broad, regularly punctate equatorial band. Polar region rounded and smooth. X20000.

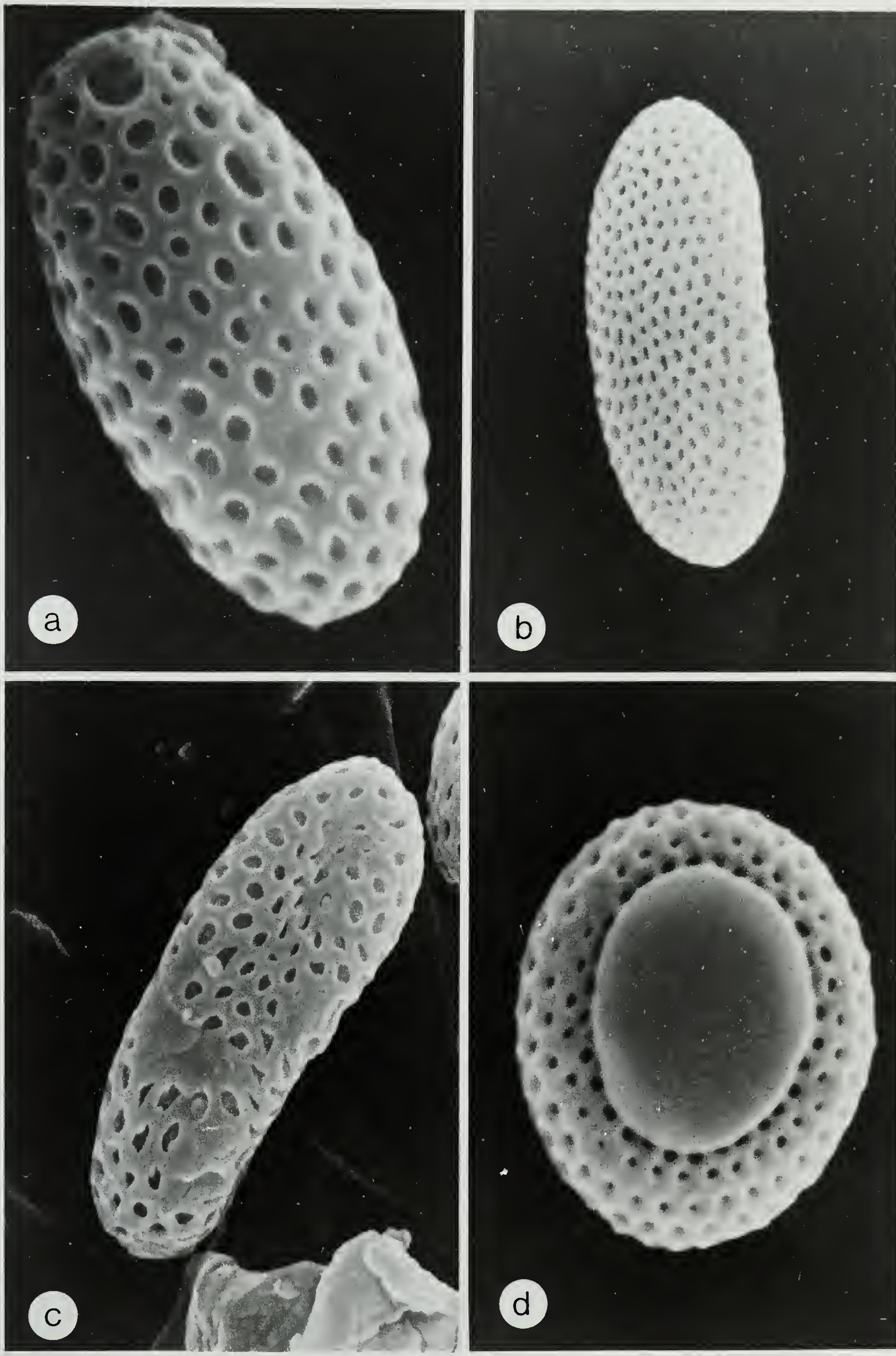
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Plate 7.16.

a *Uncinocarpus reesii* (UAMH 3882). Sparingly pitted, oblate ascospores. Puncta small, round, ridges very broad. X20000.

b *Uncinocarpus uncinatus* (TRTC 38215). Pitted, oblate (somewhat collapsed) ascospore. Puncta small and round. X20000.

c *Kuehniella racovitzae* (NY O-3436). Irregularly punctate, ridged, globose, somewhat collapsed ascospore. X23000.

d *Spiromastix warcupii* (UAMH 1668). Oblate ascospores with numerous minute pits. X20000.

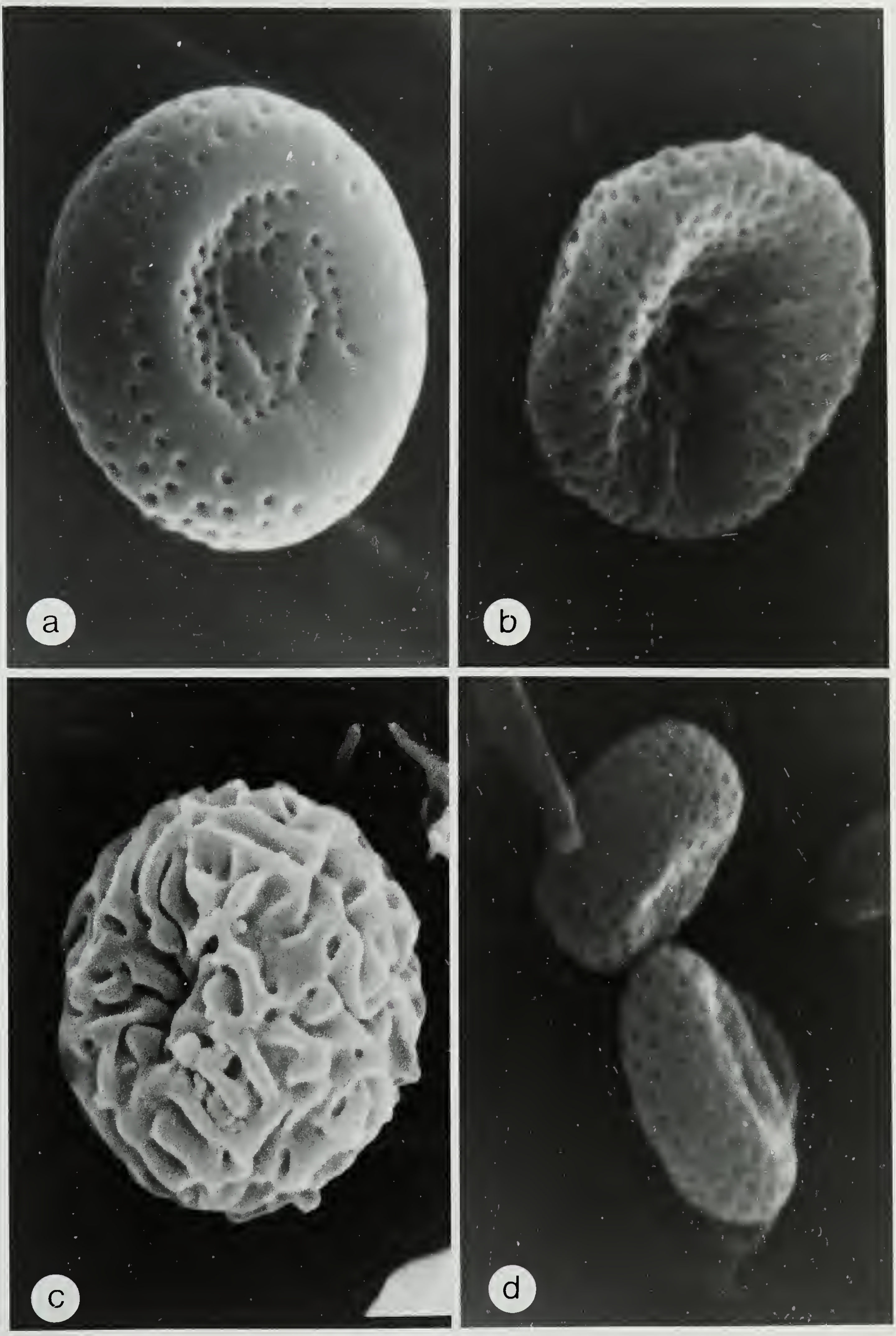
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Plate 7.17.

**a** *Xynophila mephitalis* (UAMH uncatalogued). Free hand section of fruit body showing outer tomentose layer of hyphae and inner conglomeration of ascospores (arrow). X1250.

**b** *Spiromastix warcupii* (RSA 1293). Ascoma with a peridium of thick-walled, curved hyphae. X1500.

**c** *Xynophila mephitalis* (UAMH uncatalogued). Membranous peridium. X1850.

**d** *Spiromastix warcupii* (RSA 1293). Ascomata of various sizes; nearly confluent. X400.

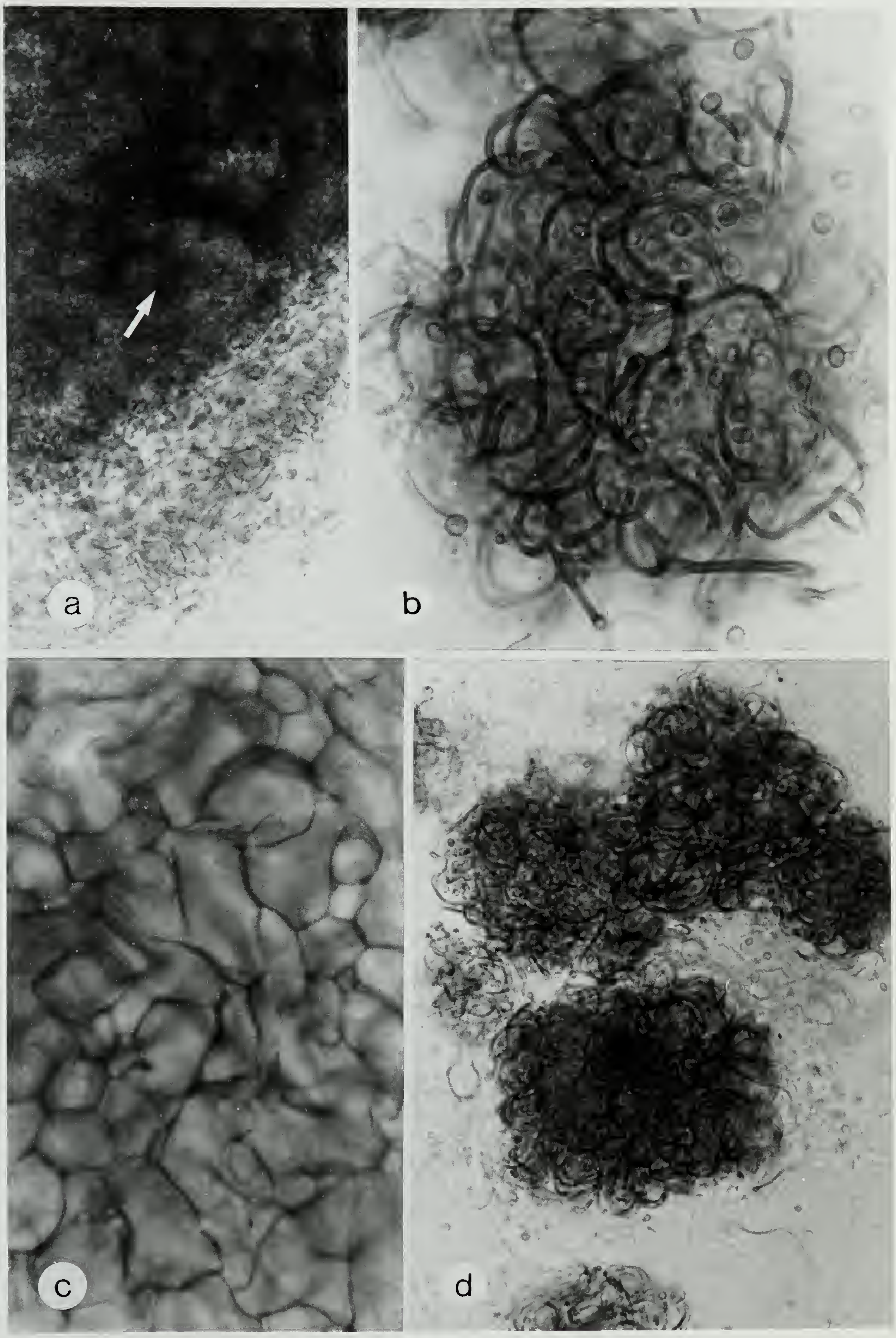
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Plate 7.18.

**a** *Uncinocarpus uncinatus* (FH "hen dung"). Smooth, thick-walled, uncinate appendages; ascospores (arrow) oblate, and apparently smooth. X715.

**b** *Uncinocarpus uncinatus* (FH "hen dung"). Tangential view of outer surface of ascoma. X308.

**c** *Uncinocarpus reesii* (UAMH 3703). Intercalary conidia of *Malbranchea* anamorph. X830.(Phase contrast photomicrograph).

**d** *Uncinocarpus uncinatus* (FH "hen dung"). Two interlocked ascomata. X505.

**e** *Uncinocarpus reesii* (UAMH 3882). Thick-walled, uncinate appendage with tapered distal end, and oblate ascospores. X830.(Phase contrast photomicrograph).

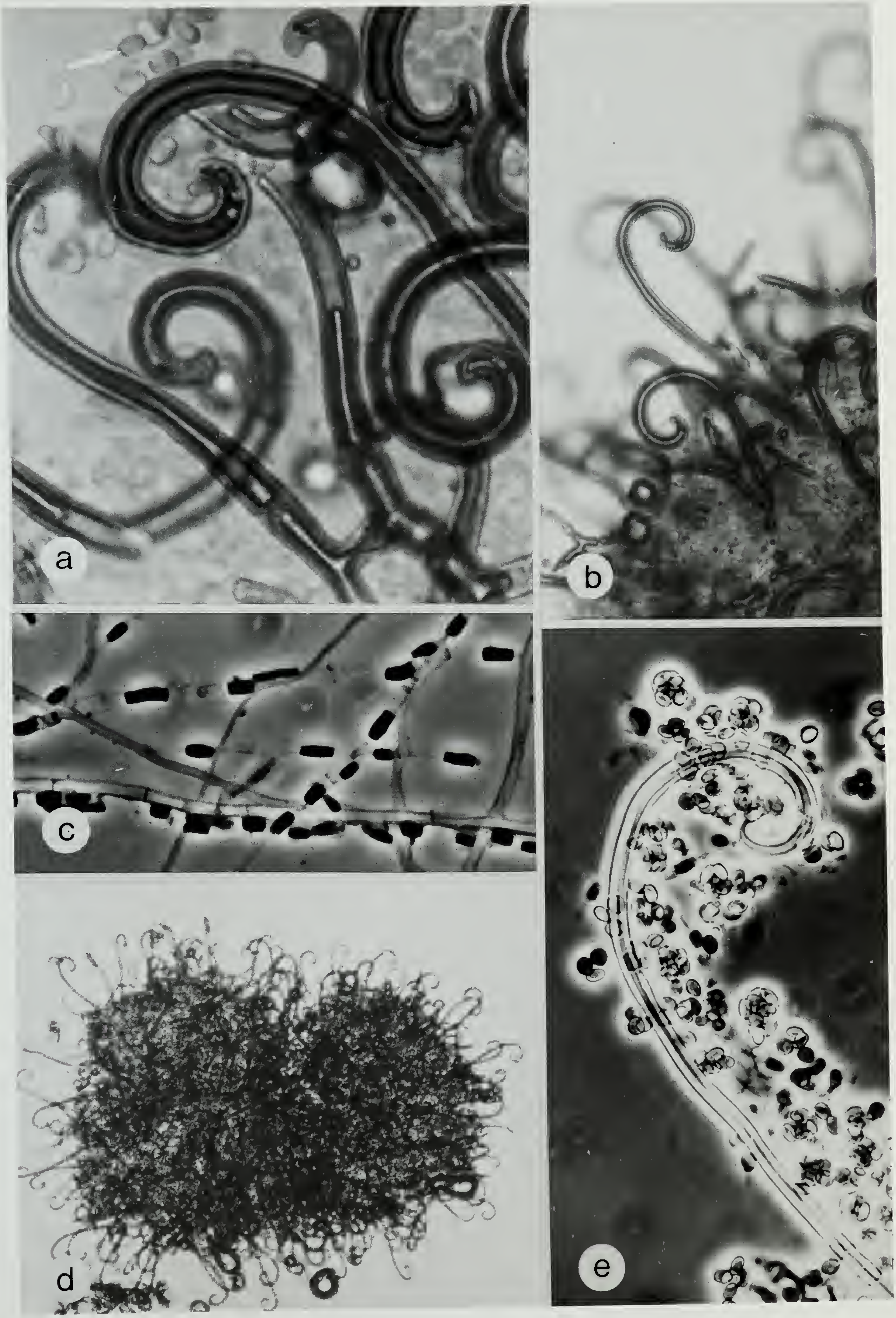
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Plate 7.19.

**a** *Shanorella spirotricha* (UAMH 4765). Oblate ascospores with fine round puncta. X11500.

**b** *Renispora flavissima* (UAMH 4205). Large, globose, spiny macroconidium. X8500.

**c** *Arachnotheca glomerata* (UAMH 3551). Ascospores with membranous sheath. X14500.

**d** *Shanorella spirotricha* (UAMH 4765). Thick-walled, irregular, disarticulated hyphae of incompositothecium. X1250.

**e** *Shanorella spirotricha* (UAMH 4765). Elements of the incompositothecium and ascospores as they appear in a squash preparation. X500.

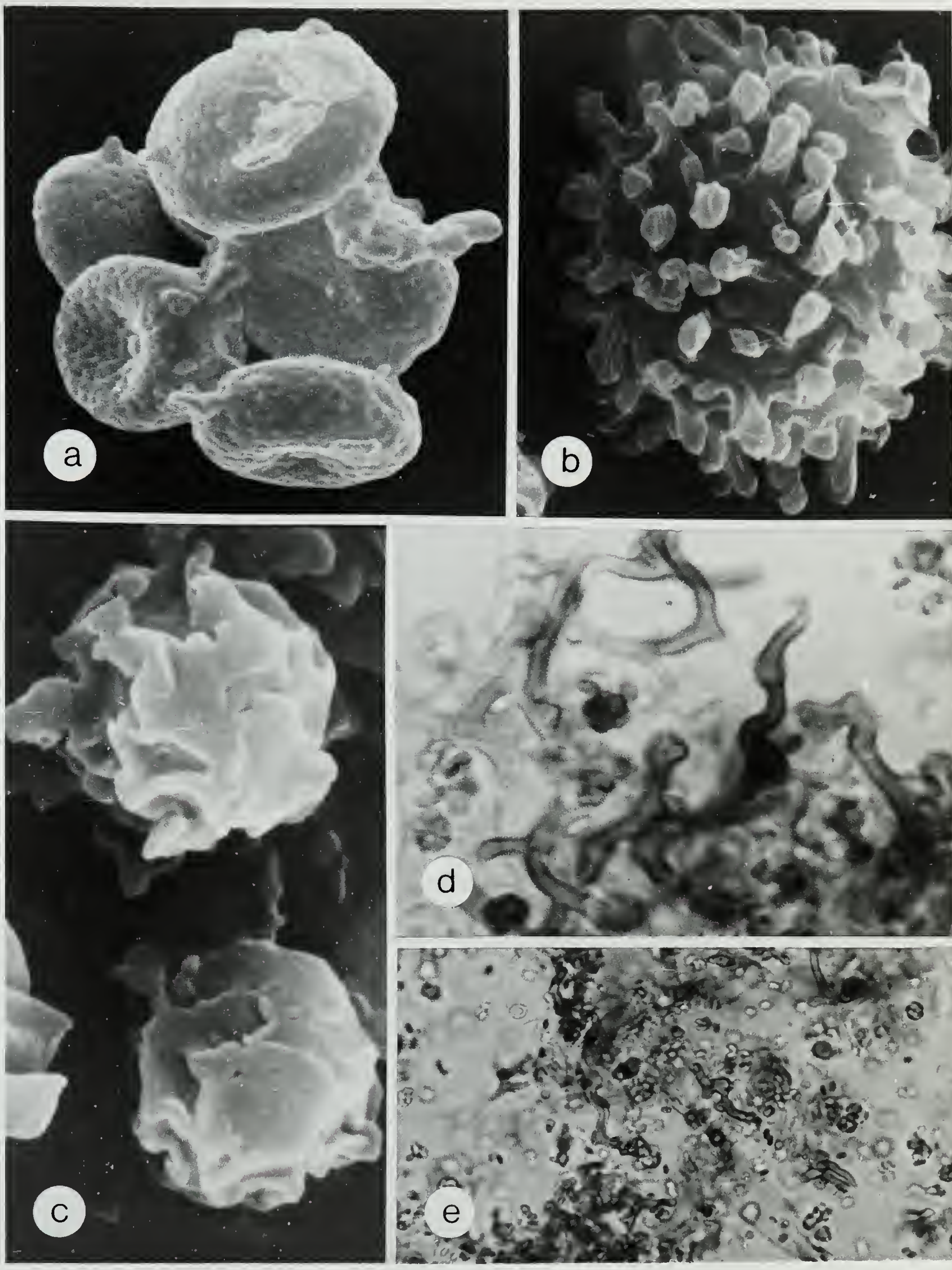
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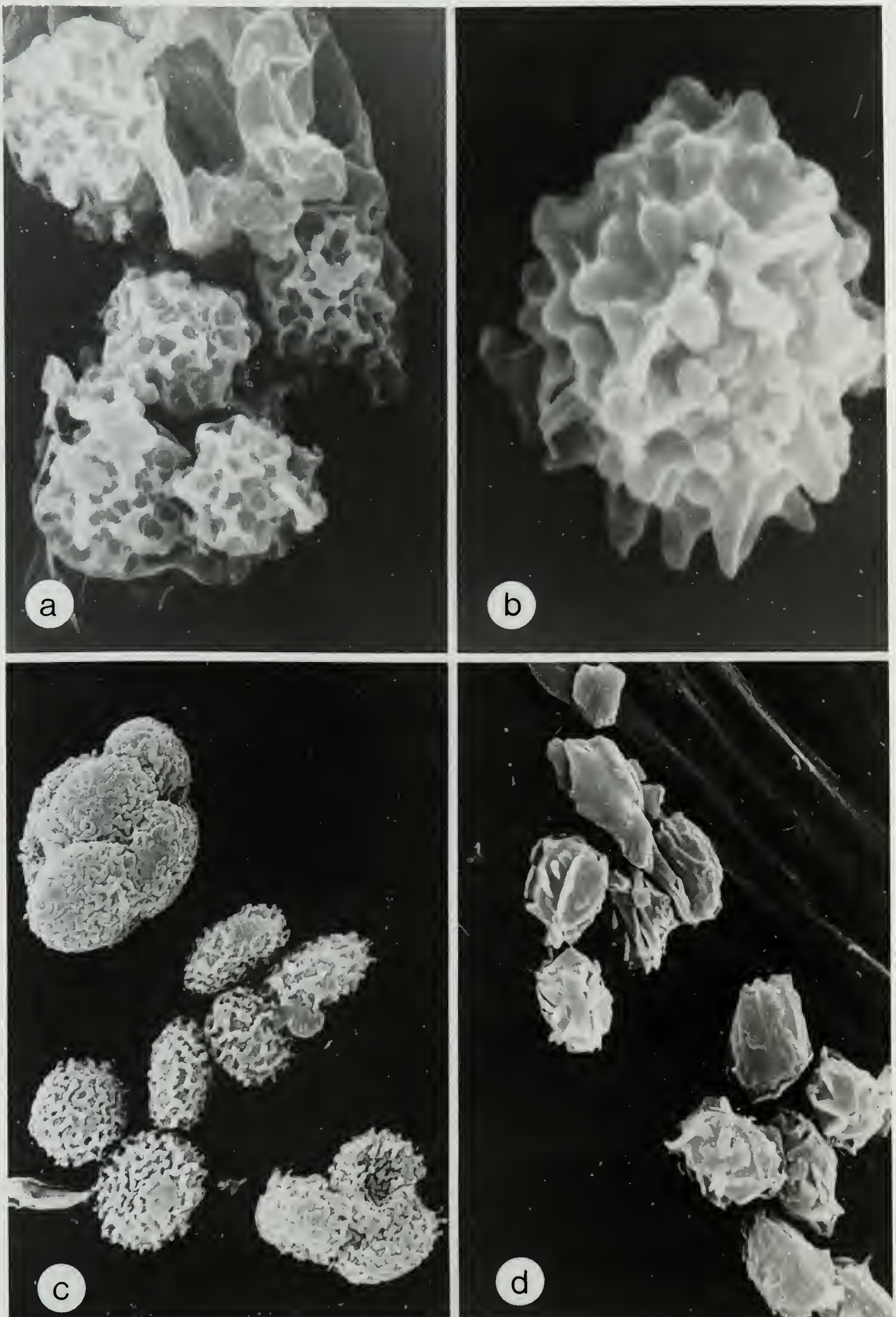
Plate 7.20.

**a** *Amauroascus niger* (UAMH 3544). Thick-walled ascospores with irregular pits. X6625.

**b** "*Amauroascus echinulatus*" (UAMH 3561). Ascospore ornamented with broad, blunt spines. X16000.

**c** *Aphanoascus fulvescens* (UAMH 4603). Ascospores with irregular pits and ascal cluster. X4000.

**d** "*Aphanoascus cinnabarinus*" [Udagawa and Takada] (UAMH 3652). Ascospores with narrow spine-like projections. X3250.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# CHAPTER 8

## GENERA EXCLUDED FROM THE ONYGENALES

The following is a list of generic names which have, at one time or another, been referred to either the Gymnoascaceae or Onygenaceae. The names are given with a brief note explaining why they are not included in the system used in this thesis, or with an indication under which name they can be found.

*Actinodendron* Orr and Kuehn, 1963 (Mycopathol. et Mycol. Appl. **21**:211). Name applicable to teleomorph of fungus with *Oncocladium* and *Malbranchea flava* anamorphs if ascospores are found.

*Actinospira* Corda, 1854 (Icones Fungorum **6**:7). =*Myxotrichum* q.v.

*Anixiopsis* Hansen, 1897 (Botanische Zeitung **7**:131). =*Aphanoascus*.

*Arachnomyces* Massee and Salmon, 1902 (Ann. Bot. **16**:68). Ascospores apparently smooth; gametangia strikingly different from all other Onygenales.

*Arachnotheca* von Arx, 1971 (Persoonia **6**:376). Anamorph has schizolytically dehiscing arthroconidia, ascospores have membranous sheath.

*Ascosphaera* Olive and Spiltoir, 1955 (Mycopathol. et Mycol. Appl. **47**:238). Sexual apparatus a trichogyne; ascospores formed within a spore cyst. Considered in its own class by Barr, 1983.

*Byssochlamys* Westling, 1909 (Svensk. Bot. Tidskr. **3**:134). Anamorph phialidic (in form-genus *Paecilomyces*).

*Carpenteles* Langeron, 1922 (Compt. Rend. Soc. Biol. (Paris) **87**:343). Anamorph phialidic (in form-genus *Penicillium*).

*Campsotrichum* Ehrenberg, 1819 (Jahrb. Gewachsk. **1**:55). *Nomen invalidum* see Hughes, 1968 for discussion.

*Conidiascus* Holterman, 1898 (Myk. Unters. Trop. page 23). Endomycetales *fide* Benjamin, 1956.

*Dichotomomyces* Saito ex Scott, 1970 (Trans. Brit. mycol. Soc. **51**:313). Placed in Onygenaceae by Malloch and Cain, 1970b; anamorph of schizolytically dehiscing blastoconidia.

*Dichotonium* Berkeley and Curtis, 1875 (Grevillea **3**:146). Orthographic error. Hyphomycete genus *Oichitonium* see Carmichael *et al.*, 1980.

*Diehliomyces* Gilkey, 1954 (Mycologia **46**:789). Smooth, globose, thin-walled ascospores.

*Diplostephanus* Langeron, 1922 (Comp. Rend. **87**:344). *Eurotium* teleomorph of *Aspergillus fide* Thom. See Ainsworth, 1961.

*Disarticulatus* Orr, 1977 (Mycotaxon **6**:33). based on *Gymnascella devroeyi* q.v.

*Eidamella* Matruchot and Dassonville, 1901 (Bull. Soc. Mycol. Fr. **17**:129). =*Myxotrichum deflexum* q.v.

*Eleutherascus* von Arx, 1971 (Persoonia **6**:77). Large spiny ascospores to 12*um* diam.; no anamorph. "Primitive discomycete" (von Arx) *op. cit.*

*Emmonsiella* Kwon-Chung, 1972 (Science **177**:368). =*Ajellomyces* q.v.

*Galactomyces* Redhead and Malloch, 1977 (Can. J. Bot. **55**:1701). Schizolytically dehiscing arthroconidia; ascospores with furrow.

*Hexagonella* Stevens and Guba, 1925 (Bish. Mus. Bull. **19**:89). Epiphyllous on *Pellaea rotundifolia* (Pteridophyte) and large, 3-celled ascospores.

*Leucothecium* von Arx and Samson, 1973 (Persoonia **7**:378). Arthroconidia dehisce schizolytically.

*Lilliputia* Boudier and Patouillard, 1900 (Bull. Soc. Mycol. Fr. **16**:144). =*Roumegueriella fide* Malloch and Cain, 1972a (in Trichocomaceae) see Benny and Kimbrough, 1980.

*Macronodus* Orr, 1977 (Mycologia **5**:283, 1977). =*Auxarthron* q.v.

*Myrillium* Clements and Shear, 1931 ( *Species incertis est.*) (see Benjamin, 1956).

*Narashimella* Thirumalachar and Mathur, 1966 (Sydowia **20**:184). =*Gymnascella marginospora* q.v.

*Penicilliopsis* Solms-Laubach, 1887 (Ann. Jard. Buitenz. **6**:53). "usually included in the Eurotiaceae" (Benjamin, 1956).

*Petalosporus* Ghosh, Orr and Kuehn, 1963 (Mycopathol. et Mycol. Appl. **21**:36). =*Gymnascella* q.v.

*Pleuroascus* Massee and Salmon, 1901 (Ann. Bot. **15**:330). Possibly Onygenaceae; excluded here until further study.

*Plunkettomyces* Orr, 1977 (Mycotaxon **6**:33). =*Gymnascella* q.v.

*Pseudoarachniotus* Kuehn, 1957 (Mycologia **49**:694). =*Gymnascella* q.v.

*Rollandina* Patouillard, 1905 (Bull. Soc. Mycol. Fr. **21**:81). =*Nomen confusum*.

*Thermoascus* Miehe, 1907 (Die Selbsterhitzung des Heues, Jena pp 70-73). Placed in Onygenaceae by Benny and Kimbrough, 1980; excluded here since there is no evidence of keratinolytic abilities nor, does it have strictly rhexolytically dehiscing conidia.

*Toxotrichum* Orr and Kuehn, 1964 (Mycologia **56**:473). =*Myxotrichum*.

*Tripedotrichum* Orr and Kuehn, 1964 (Mycologia **56**:482). Dark oblate ascospores described by Orr are probably conidia of dematiaceous hyphomycete.

*Waldemaria* Batista, Maia and Cavalcanti, 1960 (Atas. Inst. Micol. (Recife). **1**:6. =*Gymnascella* q.v.

*Xanthothecium* von Arx and Samson, 1973 (Persoonia **7**:377). Possibly Onygenales; decision reserved until further study.

*Xylogone* von Arx and Nilsson, 1969 (Svensk. Bot. Tidskr. **63**:345). Schizolytically dehiscing arthroconidia.

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